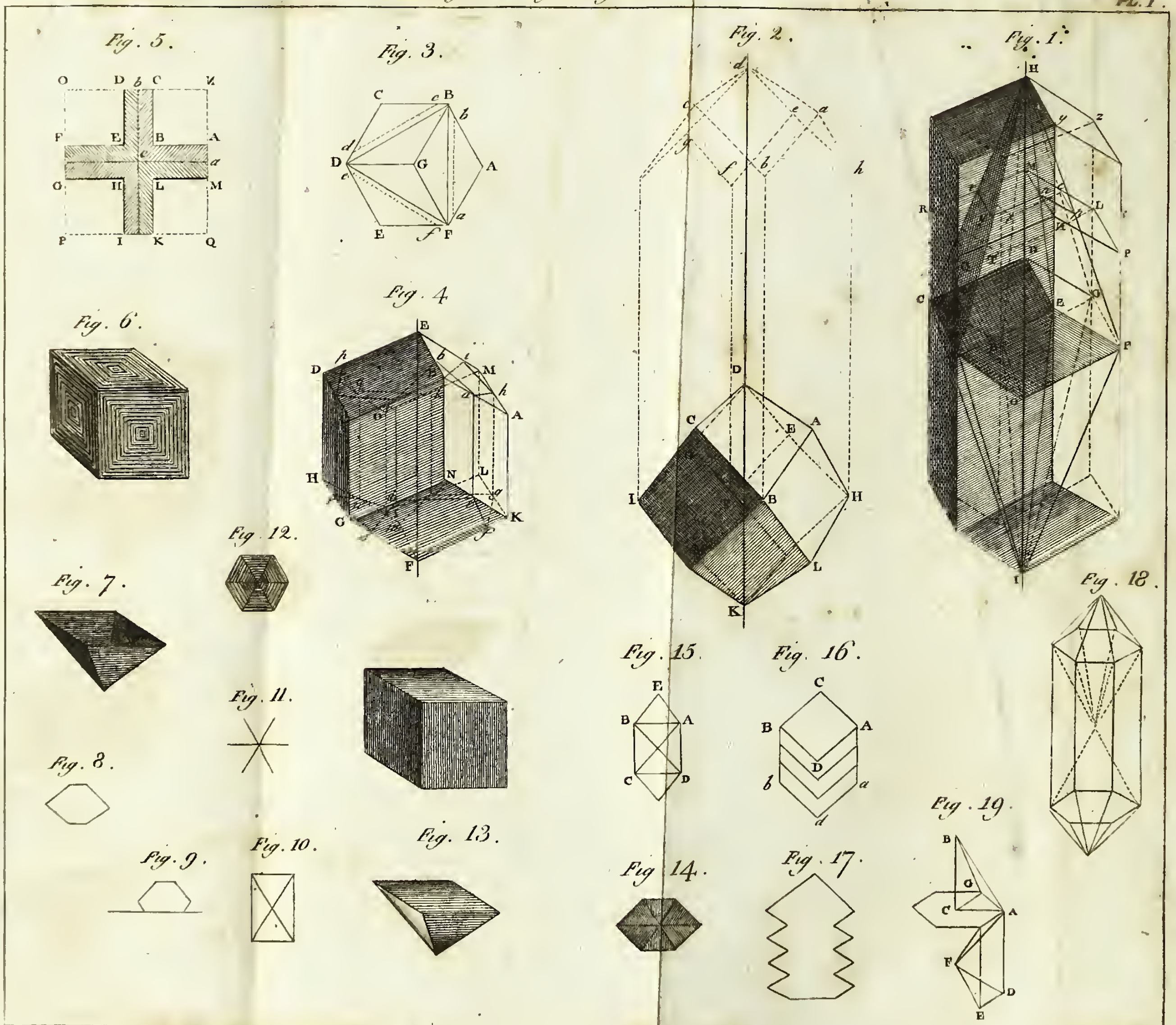
PL. I.



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PHYSICAL AND CHEMICAL ESSAYS;

TRANSLATED FROM THE ORIGINAL LATIN OF

SIR TORBERN BERGMAN,

KNIGHT OF THE ORDER OF WASA, PROFESSOR OF CHEMISTRY AT UPSAL, &c. &c. &c.

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TO WHICH ARE ADDED

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BY THE TRANSLATOR.

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M.DCC.LXXXIV.

Hominis imperium in Res, in solis Artibus & Scientiis ponitur. Naturæ enim non imperatur, nisi parendo —— Si quis depravationem Scientiarum & Artium ad malitiam & luxuriam & similia objecerit; id neminem moveat. Illud enim de omnibus mundanis bonis dici potest, Ingenio, Fortitudine, Viribus, Forma, Divitiis, Luce ipsa & reliquis. Recuperet modo genus humanum jus suum in Naturam, quod ei ex dotatione divina competit; & detur ei copia; usum vero recta ratio & sana religio gubernabit.

BACO DE VERULAMIO.

TO THE

ILLUSTRIOUS

ROYAL SOCIETY

FOR THE PROMOTION OF SCIENCE

AND POLITE LITERATURE

AT BERLIN,

THIS VOLUME IS DEDICATED

BY THE AUTHOR,

WHO WAS CHOSEN A FELLOW

WHEN HE WAS PRESENT.

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Philosophia naturalis scripta est in maximo isto libro, qui continue nobis ante oculos jacet apertus (universum hoc ajo), sed nihil aut in eo legi, aut intelligi poterit, nisi prius addiscatur idioma, quo exaratum est. Characteres ejus sunt triangula, circuli & aliæ figuræ geometricæ. GALILÆUS.

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Sunt aliquot quoque res, quarum unam dicere causam
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Heu prodigiosa ingenia, quot modis auximus pretia rerum.
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In arctum coacta rerum naturæ majestas. PLINIUS.

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Et alias invenio (gemmarum ardentium) *differentias; unam, quæ purpura radiet, alteram, quæ Cocco; a ſole excalefactas aut digitorum attritu, paleas & chartarum fila ad ſe rapere.*
PLINIUS.

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Quælibet res nihil præſtare poteſt præter id, quod in ſe eſt & continet. GEBER.

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Multa sæculis tunc futuris, cum memoria nostri exoleverit, reservantur; veniet tempus, quo ista, quæ nunc latent, in lucem dies extrahet & longioris ævi diligentia. Rerum enim natura sacra sua non simul tradit; initiatos nos credimus, in vestibulo ejus hæremus; illa arcana non promiscue, non omnibus patent, reducta & interiori sacrario clausa sunt; involuta veritas in alto latet. Seneca.

§ 7. *Pro-*

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Quam pulchrum eſt, in principiis, in origine rerum
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F. Baco de Verulamio.

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Nec manet ulla sui similis res; omnia migrant,
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Intumeſcent

DISSER-

DISSERTATION XII.

OF THE

FORMS OF CRYSTALS,

PARTICULARLY THOSE OF

THE SPATHACEOUS KIND.

---

§ 1. *Infinite Variety of the Forms of Cryſtals.*

CRYSTALS are bodies which, though deſtitute of organic ſtructure, yet externally reſemble geometrical figures, more or leſs regular. If we attend to the numerous collections of theſe, we ſhall be ready to conclude, that nature has effectually eluded our reſearch by the infinite variety; for frequently bodies widely differing in their nature and properties reſemble one another in figure; and, on the contrary, thoſe which are exactly alike in properties put on external appearances entirely different; yet, upon a careful examination and comparifon of this variety of figures, we ſhall find, that a great number of them, though their ſurfaces differ with reſpect to their angles and ſides, may be derived from and referred to a very ſmall number of ſimple figures.

Unleſs thoſe figures, which are not improperly called primitive, be thoroughly inveſtigated, the whole doctrine of cryſtallization will ſtill continue to be, as it has been heretofore, a perfect chaos; and thoſe who undertake the deſcription or methodical diſtribution of cryſtallized bodies, will inevitably loſe their labour. For a ſeries of years I have conſidered this intricate ſubject with much attention; and I hope that my efforts have not been altogether void of ſucceſs. I proceed to exhibit ſome ſpecimens chiefly from the order of ſpathaceous cryſtals, and ſhall then endeavour to explain (as far as can be done upon a plane ſurface) how the ſpathaceous cryſtals, ſuitably agglutinated together, may form the great variety of diſſimilar bodies which are to be found among cryſtals.

§ II. *Various Figures derived from the ſpathaceous Form.*

The calcareous ſpar, as is well known, conſiſts of a teſſera, or oblique parallelopiped;

ped; all whoſe planes are rhombi of ſuch a kind, that the obtuſe angles are equal to 101½°, and the acute to 78½°. Let us now ſee how, by a proper accumulation of ſuch ſimilar parallelograms, cryſtals of the moſt oppoſite forms may be generated.

(A) Let A C E G O, fig. 1. tab. 1. repreſent a ſpathaceous nucleus, through whoſe oppoſite angles, D O, the axis H O paſſes: let us ſuppoſe, that contiguous rhombi are applied to this, above and below; and that theſe rhombi are equal, ſimilar, and parallel to the ſubjacent planes of the nucleus; theſe, to avoid confuſion in the figure, we ſhall only repreſent by the rhombi M P, M Q, and M T, which will be ſufficient for thoſe who are ſkilled in geometry and perſpective.

By this method an hexaedral priſm is generated, conſiſting of ſix equal and ſimilar parallelograms, and terminating at both ends in three rhombi, which unite, and form a ſolid angle: this form of cryſtallization belongs to ſome of the calcareous tribe, but more particularly to ſchoerls; it is therefore called the ſchoerlaceous form.

(B) If the accumulation of the planes is ſtopped when the ſides of the priſm have acquired a rhomboidal nature, we ſhall have a dodecaedron included by rhombi: this is the uſual form of garnet, when perfect.

(C) The garnetic form is eaſily changed

into another, *viz.* into that in which the hyacinth often preſents itſelf: this is effected by the regular application of equal and ſimilar rhombi to each of the ſolid angles, which are compoſed of four planes, for the garnet has ſix ſuch, when complete as to figure, and eight with three ſides; let fig. 2. be conſulted, where the dotted lines expreſs the geneſis of the priſm more intelligibly than words can poſſibly do. In this operation the four rhombi are changed into an equal number of oblong hexagons: L H A B into L H h a b B, &c. &c. &c.

(D) Sometimes planes are applied, ſimilar indeed to the fundamental planes, but decreaſing according to a certain law: this decreaſe, whether owing, as is moſt probable, to a deficiency of matter, or to ſome other cauſe, muſt neceſſarily change the appearance of the terminating planes, and occaſionally either augment or diminiſh their number. Let us now return to fig. 1.—ſuppoſe ſimilar planes, but continually decreaſing (M p, M q, M t), applied to the internal nucleus, theſe will ultimately end in an apex on both ſides; ſo that, inſtead of a priſm, we ſhall have a double pyramid, one tending upwards, the other downwards: at the ſurface the planes which meet form interſections or common baſes, whoſe angles alternately tend upwards and downwards, as is ſhewn by G F E A C B G: this is the form of of the calcareous cryſtals, which are called by the miners pig-tooth ſpars (*dentes ſuilli.*)

It is evident, that the axes of the pyramids are the longer, in proportion as the rhombi decreaſe more ſlowly; and the contrary.

If the decreaſing ſeries is ſtopped before the ultimate ſides of the accumulated planes vaniſh, truncated apices will be generated; of which frequent examples occur.

In the calcareous pyramidal cryſtal juſt deſcribed, if the dorſal margins A H, B H, or F H, be cautiouſly ſtruck, they break off into ſpathaceous teſſeræ; but this is not the caſe with the alternate margins C H, E H, and G H, which it is ſcarce poſſible to bring to that ſtate; the reaſon is evident—in the former caſe the direction of the blow is parallel to the accumulation of the planes; whereas, in the latter, it meets the interſection of two planes:—this property alſo obtains in the lower pyramid, with this difference, however, which neceſſarily reſults from the very ſtructure, namely, that the margin A I muſt produce a directly oppoſite effect from the margin A H; and the ſame is true of the reſt, *mutatis mutandis*.

(E) Frequently, alſo, the fundamental planes themſelves are imperfect; if, in this caſe, planes ſimilar to them be added, forms of cryſtals muſt be generated more or leſs unlike the perfect form.—Examples of this are very numerous; but in this place it will be ſufficient briefly to explain a few.

Let A B C D E F G, fig. 3, repreſent the three rhombi which conſtitute the apex of a perfect ſchoerlaceous cryſtal; let us now ſuppoſe the rhombus A G truncated in the direction of the line a b; C G along c d; and E G along e f. This being the caſe, the regular hexagonal figure of the priſm A B C D E F is changed to an irregular one, a b B c d D e f F, conſiſting of nine unequal ſides, whoſe apex is compoſed of three irregular pentagons, a b B G F, c d D C B, and e f F G D. I have now in my poſſeſſion cryſtals of this form, both calcareous and ſchoerlaceous: to this claſs may be referred in general the rough turmalins, particularly thoſe of Tyrol and Ceylon, of which we ſhall ſpeak more expreſsly (*a*) hereafter.

It is obvious that pentagonal periphery a b B G F approaches more nearly to triangular, in proportion as the diſtance between a b and B F grows leſs; the ſame is true of the reſt: and when theſe diſtances become evaneſcent, a triagonal priſm is formed, terminated by three triangles: if the cutting line a b, c d, e f, approach ſtill nearer to the center G, and equally, the form ſtill remains the ſame.

(F) The garnetic figure may be conceived as that of an hexaedral priſm, terminated at

(*a*) De Terra Turmalini.

each

each end by three rhombi, meeting at the apex; and it may be compoſed of four equal ſpathaceous teſſeræ properly adapted; I have already mentioned its geneſis (B); and its form is marked by the capital letters in fig. 4. If now, in the place of complete rhombi, we ſuppoſe accumulated in the ſame manner about its axis others, whoſe three external angles are truncated, or, which is the ſame thing, if the longitudinal margins of the priſm be cut by planes parallel to the axis, a dodecaedron will ariſe, conſiſting of pentagons, which are indicated in fig. 4. by the ſmall letters. Calcareous cryſtals of this kind ſometimes occur, but they are generally ſo low, that e nearly coincides with a, c with d, &c.; ſo that the pentagon a b c d e becomes almoſt of a triangular figure, which is the figure attributed to them by ſome authors, who are ignorant of their true nature. Among the pyritacea we may ſometimes obſerve inſtances of this variety complete.

Sometimes all the margins of the garnet are truncated, ſo that the number of including ſides increaſes to twenty-four oblong hexagons; a change which may eaſily be derived from the poſitions already laid down. If the interſection c d, of the planes e c and c r, falls without the plane B G, a figure of a very different kind will be generated.

 (G) The

(G) The hyacinthine figure (art. C) alſo ſometimes labours under defects peculiar to itſelf. I ſhall mention one very remarkable variety which is met with in Hartz mines (*b*): there the cryſtals ſometimes appear of a cruciform figure (A B C D E F G H I K L M, fig. 5.); the apex is at C, the figure A B C b c a is all in the ſame inclined plane; and that is the caſe with the other three homologous figures. Now, in order to inveſtigate the primitive form, let the rhombi C N, C O, C P, and C Q be completed there, to an eye placed high in the axis, paſſing through C, will appear like ſquares ſituated in the ſubjacent plane, and we ſhall have the rudiments of this hyacinthine figure: for we may alſo conceive the granite form as a quadrangular priſm, compoſed of four rhombi, touching one another only in their apices, and terminated at each end in four rhombi, meeting at the apex. This form, if a little protracted, or, what is the ſame thing, encreaſed by applying to the apices ſimilar and equal planes, becomes the hyacinthine form, and therefore may without impropriety be denominated the rudiment of it.

(H) If the added planes be ſimilar to one another, but not ſimilar to the fundamental planes, prodigious varieties will ariſe from hence; but I think it unneceſſary at pre-

(*b*) F. Ehrhart, that unwearied obſerver of nature, ſent me ſome of theſe: they are ſiliceous, not calcareous, though they have the appearance of the latter.

ſent

ſent to multiply examples, as what has been already ſaid, if well underſtood, will be found abundantly ſufficient to ſhew how, by a plain and ſimple method, many other figures may be reduced to the primitive forms.

(I) If any one imagines this doctrine to be purely geometrical and ſpeculative, let him carefully examine the calcareous cryſtals, the looſe texture of which, if cautiouſly and ſkilfully broken, will completely ſhew the internal ſtructure (*c*) : as to the harder cryſtals, endowed with the forms above mentioned, their parts cohere ſo ſtrongly that they can ſcarcely be broken : the ſchoerls exhibit the ſpathaceous texture very plainly ; and there is no doubt, but the garnets themſelves are compoſed of lamellæ, as will readily appear to an attentive eye.

(K) Finally, we may add one peculiar obſervation concerning priſmatic and hexagonal calcareous cryſtals, truncated perpendicularly ; ſuch ſometimes occur, and they cannot derive their origin, in the manner above deſcribed, from the ſpathaceous particles, and by no other way can hexagonal priſms be generated : what then is the cauſe which deſtroys their apices ? —I confeſs this to be a queſtion which I am wholly unable

(*c*) My pupil, Dr. Gahn, firſt obſerved the central nucleus in pyramidal calcareous cryſtals.

to anſwer, unleſs we may aſſume an accumulation of planes, more and more deficient around the axis. We may from hence conclude, that ſomething unuſual occurs, as the truncated extremity is opaque, while the reſt of the priſm is tranſparent; but the upper hexagonal ſection is ſmooth and poliſhed.

(L) We have ſeen then priſms of three, four, ſix, or nine ſides, occaſionally terminated by various apices: we have ſeen pyramidal, dodecaedral, cruciform, and other very different figures, generated from the ſame ſpathaceous form: beſides, we ſhall obſerve, that theſe almoſt all occur, though the nature of the ſubſtance remains the ſame; and from thence we ſhould be induced to put but little confidence in figure. If then this teſt, which undoubtedly is the moſt remarkable, ſo far as externals reach, is of ſo little uſe, of what value can the others be?—and with what ſucceſs can we hope to form a ſyſtem of mineralogy upon ſuch diſtinctions? External criteria ſhould certainly not be neglected, but he who truſts implicitly to them deceives himſelf: they may, to an experienced obſerver, yield ſome aſſiſtance, but can never ſerve to determine his aſſent.

§ III. *Struc-*

§ III. *Structure of the most minute Parts.*

As ſo great a variety of forms may be produced by the ſpathaceous particles accumulated in different ways, it is probable that the differences of all cryſtals, with reſpect to externals, are owing to varieties in their mechanical elements. But here a queſtion may properly be ſtarted,—whether the moſt minute molecules, and as it were the ſtamina, are naturally poſſeſſed of a determinate angular figure, or whether they firſt acquire it during cryſtallization?—In anſwer to this queſtion I beg leave to mention ſome circumſtances which occurred to me in the courſe of obſervation.

(A) If the ſmall particles which ſeparate from lime-water, when expoſed to the air, be inſpected with a microſcope, they will be found ſpathaceous.

(B) The greater ſpathous teſſeræ, when accurately examined, are frequently found with ſtriæ running diagonally (ſuch as we ſhall hereafter find appear in ſaline cryſtals) which diſcover their internal ſtructure.

(C) The cubes of common ſalt not only exhibit diagonal ſtriæ, but frequently, upon each ſide, they ſhew ſquares parallel to the external ſurface, and gradually decreaſing inwards (fig. 6); circumſtances which ſhew the veſtiges of their internal ſtructure: for

for every cube is compoſed of ſix quadrangular hollow pyramids, joined by their apices and external ſurface; each of theſe pyramids filled up others ſimilar, but gradually decreaſing, completes the form. By a due degree of evaporation it is no difficult matter to obtain theſe pyramids ſeparate and diſtinct (as in fig. 7), or ſix of ſuch, either hollow, or more or leſs ſolid, joined together round a center; this is the whole courſe of the operation, from beginning to end. All this is true of the ſalited vegetable alkali, commonly called ſal digeſtivus ſylvii; of the cryſtallized luna cornea (*d*); of the galena, or ſulphurated lead, which is frequently to be generated at Fahlun in the heaps, roaſted, as it is called *ſub dio frigide*; quadrangular nitre too, which is of the ſpathous form, produces a ſimilar congeries of pyramids, and theſe almoſt equally diſtinct with the preceding cubic cryſtals. A ſolution of alum, upon evaporation, does generally produce ſolid octaedra; but ſometimes it alſo exhibits hollow pyramids, and upon ſuch of them as are complete the junctures are very diſtinctly marked by conſpicuous lines.

(D) Sometimes too other ſalts indicate the ſame conſtruction by viſible diagonals. The Rochelle ſalt forms an hexagonal priſm; a ſection of which is ſhewn by fig. 8:

(*d*) C. H. Lommer, vom Hornertza.

when

when this kind of cryſtal is complete, the manner of arrangement among the internal particles is entirely unknown; but when the cryſtal is formed on the bottom of the veſſel, the lower ſide cannot be perfect (fig. 9); and this parallelogram exhibits two diagonals diſtinctly (fig. 10.) This is alſo the caſe with the ſalt extracted from human urine, which is called microcoſmic ſalt: beſides, we ſhould obſerve of the vertical triangles, that they are alternately tranſparent and opaque in pairs; which plainly points out a difference in the ſituation of their elements. I have alſo ſome cryſtals of nitre marked with diagonals, a circumſtance which in others is generally concealed by the cloſe connection of the particles.

(E) If we examine the hollow pyramid of common ſalt farther, we ſhall find it compoſed of four triangles, and each of theſe formed of threads parallel to the baſe; which threads, upon accurate examination, are found to be nothing more than ſeries of ſmall cubes: therefore, although the above circumſtances ſeem plainly to point out the geneſis of all cryſtals, from the union and coheſion of pyramids, whoſe ſides, being different in form and magnitude, occaſion the differences of forms; it yet remains uncertain whether the ſame internal ſtructure takes place in thoſe whoſe minuteneſs renders them totally inviſible; and whether the primary ſtamina poſſeſs a determinate figure, or

are

are compoſed by the union of many ſhapeleſs particles. We have long known that the ſmalleſt concretions which are viſible by the microſcope, poſſeſs a determined figure;—but theſe are compounds: in the mean time, until this veil is in ſome meaſure at leaſt removed, we cannot avoid comparing the proceſs of cryſtallization with the congelation of water.

While the watery particles are concreting they exert a double tendency; by one of which they are formed into ſpiculæ, by the other theſe ſpiculæ are ranged in ſuch a manner, with reſpect to one another, as to form angles of 60°: from hence the varieties obſerved in the particles of ſnow may be eaſily explained. The moſt ſimple figure is that where ſix equal radii diverge from a center, in the angle above-mentioned (fig. 11.) (*e*); the ſame angle will be preſerved if the extremities of theſe be joined by right lines; which will alſo be the caſe, if each of the triangles, thus formed, be filled with right lines parallel to the baſe fig. 12. I have alſo ſeen hexagonal figures in ſnow;—but this by the bye.

Let us now ſuppoſe the particles which are employed in cryſtallization endowed with a tendency to form ſpiculæ, and theſe ſpiculæ with a tendency to arrange them-

(*e*) Mairan on Ice.

ſelves

ſelves at equal angles of inclination, and we ſhall have both the triangles and the pyramids compoſed of them, even although the primary ſtamina had not a determined figure; as the angles of inclination vary, the triangles and pyramids will alſo vary; and hence the different forms of cryſtals will be produced, which may to a certain degree be inveſtigated geometrically, the angles being given.

We have hitherto ſuppoſed the exiſtence of a double tendency, becauſe the effect ſeems to be twofold; but both theſe effects may undoubtedly be owing to the ſame cauſe, namely, to a mutual attraction between the particles, which, according to various ſituations and peculiar figures of the atoms, at one time arranges them in the form of ſpiculæ, again connects the ſpiculæ already formed under equal angles of inclination.— I conſider the mechanical elements as exiſting under determinate and peculiar figures, as, upon any other ſuppoſition, I find it impoſſible to aſſign a cauſe which ſhould arrange different ſubſtances under different angles, and yet preſerve theſe angles always conſtant in the ſame ſubſtance. But I do not wiſh to examine this conjecture any further, though it appears to me to be probable; becauſe powdered reſin, which muſt doubtleſs conſiſt of particles of a great variety of forms, when ſprinkled on an electrophorus

phorus is, by the electric fluid, formed into ſtars like thoſe of ſnow (*f*).

§ IV. *In how many different Ways Cryſtals are generated.*

In order that the particles may be arranged, by the power of attraction, into determinate ſymmetrical forms, it is neceſſary that they ſhould be at liberty, and very eaſily moveable. The beſt method of obtaining this end is to immerſe them in ſome fluid of nearly the ſame ſpecific gravity with themſelves (*g*): this may be done in three different ways; 1. by water; 2. by a liquefying heat; 3. by a volatilizing heat.—Theſe we ſhall conſider in order.

(A) The moſt common method of cryſtallizing is by means of water, as it eaſily takes up ſaline matters, and, upon being ſufficiently diminiſhed by evaporation, yields them again in a concrete ſtate; nay, until now it has been thought, that without this vehicle no cryſtals could be obtained.

But it is not only when actually diſſolved in water that they require determinate forms; this, unleſs I am miſtaken, is alſo the caſe when they are only ſufficiently attenuated and mixed with it: for ſubſtances

(*f*) Lichtenberg firſt obſerved theſe reſinous ſtars.
(*g*) Morveau *Digreſſ. Academiques.*

not

not ſoluble in water will yet remain ſuſpended in it, if by ſufficient diviſion they have acquired ſo great a ſurface, in proportion to their maſs, as to approach the ſpecific gravity of the fluid: now ſuch particles doubtleſs poſſeſs attraction, they alſo poſſeſs the neceſſary degree of mobility; no reaſon therefore appears why they may not form cryſtals. And it ſeems highly probable that many of the earths which occur in the mineral kingdom ſymmetrical and of a regular form, have coaleſced in this way.

A mechanical mixture and a true ſolution ſhould be carefully diſtinguiſhed, although they agree in weight. In the former caſe the particles, if collected and laid upon the bottom of the veſſel, will remain there, unleſs diffuſed by agitation. A ſubſtance which is ſoluble, on the contrary, is totally and ſpontaneouſly diſtributed through the menſtruum, even without any agitation; though the operation is certainly accelerated by agitation.

(B) Cryſtals may frequently be obtained by fuſion and ſlow cooling: the matter of heat, in ſufficient quantity, penetrating ſolid bodies which are not organic, ſoftens and liquefies many of them; for when it penetrates and looſens the texture of the maſs, it communicates mobility to each of them, ſo that upon ſlow refrigeration they are in a condition to obey the laws of that attraction which tends to arrange them in a regular manner: thus ſulphur, when melted and cooled, exhibits ſtriæ, and at the ſame time acquires an electrical property: biſmuth, zinc, and regulus of antimony, acquire a ſort of teſſelated appearance; nay, the laſt of theſe, when ſet to cool in a conical mold, becomes ſtellated, not only on the upper ſurface or baſis of the maſs, but along the whole axis. Glaſs, if melted and ſlowly cooled forms beautiful cryſtals (*h*). I have taken the ſcoriæ from furnaces where iron was fuſed, by the addition of a calcareous ſtone, and have ſometimes found them of a regular priſmatic figure. When crude iron is melted with lime, I have found complete octaedra in the ſcoriæ.

In large metallic maſſes, ſuch eſpecially as are difficult of fuſion, the lower particles are generally ſo much preſſed by the weight of the ſuperior, that they ſhew no ſigns of cryſtallization, although on the upper ſurface of gold, ſilver, iron, and others, beautiful cryſtals are formed.

It will perhaps be thought extraordinary, by thoſe who have not well weighed the matter, that I ſhould refer the congelation of water to an operation of this ſort; but we muſt conſider, that it is by means of the matter of heat that water is fluid (*i*); and

(*h*) Keir, Phil. Tranſ. for 1776.

(*i*) Phlogiſton, the matter of heat, and fire, ought to be carefully diſtinguiſhed; phlogiſton, combined with pure air and that when this matter is diminiſhed to a certain degree, it cryſtallizes and becomes ice. We have before (§ III. E.) compared congelation to cryſtallization: in this place we ſhall add another mark of reſemblance.

Snow or ice, put into hot water, by its ſolution abſorbs a quantity of heat, equal to 72° of our thermometer: the cryſtallized neutral ſalts produce the ſame effect, that is, they make the water colder, although the ſalts and the water had been kept in the ſame place for many days: for by diſſolving they acquire a larger ſurface, and by that means are able to take up and retain a portion of the matter of heat; which, being fixed, loſes its power of heating, and conſequently the thermometer ſinks when put into the water. Hence it follows, on the other hand, that the heat ſhould be increaſed during cryſtallization; and this increment is eaſily obſervable when a large quantity concretes at once: in concreting the ſurface is diminiſhed; hence, ſo great a quantity of the matter of heat cannot be retained: what is ſuperfluous, being ſet at liberty, recovers its property of heating, which it accordingly exerts, and that in proportion to its quantity.

air in a certain proportion, conſtitutes the matter of heat: fire is the action by which a proper body is deprived of phlogiſton, by means of pure air, with ſuch vehemence as to generate not only heat, but flame.

(c) Heat not only liquefies but volatilizes certain bodies: the material cauſe of heat penetrates the integrant parts, expands, attenuates, and, by its union with them, renders them ſo light, that they mount in the air: particles, after undergoing this proceſs, when during cooling they are ſufficiently at liberty, often obey the laws of attraction, and form cryſtals: to this claſs we may refer thoſe which are condenſed from the vapours of regulus of antimony, called the flores argentini. The galena, which is frequently interſperſed among the copper ore, at Fahlun, from the heaps which are there roaſted without heat, ſends forth a vapour which condenſes on the upper ſtrata, forming hollow pyramids, which form the baſes of the cubes of galena, entirely ſimilar to thoſe which compoſe common ſalt.

In the heaps of ore of arſenic which are expoſed to the fire at Loefa, I have collected extremely beautiful white, yellow, and red cryſtals, partly tetraedral, partly octaedral: ſome of theſe exhibit hollow pyramids, whoſe ſides conſiſt of threads parallel to the baſe, preciſely in the ſame manner as the cryſtals formed in the humid way (§ III. E.); ſo that through the whole proceſs of cryſtallization, a mechaniſm every where the ſame, and analogous to cryſtallization ſeems to be employed: — nor let any one imagine, that theſe are to be conſidered as monſtrous

monſtrous productions, which throw no light upon the theory of cryſtallization; for theſe cryſtals, when complete, frequently ſhew the junctures of the pyramids, by very diſtinct lines; and, by proper addreſs, we may be able to ſee the proceſs through its various ſteps, from the firſt rudiments to the completion of the whole operation. If this ſtructure, as is very probable, takes place in all, yet it will not contradict what has been already ſaid concerning the ſpathous form, as elements of the ſpathous figure, properly applied, may readily form pyramids fit for this purpoſe.

A priſm of any kind may be formed by the apices of proper pyramids, meeting together in proper number round the ſame point; and the apex may alſo be formed by a ſingle pyramid, its vertical angle being turned outward: thus a four-ſided priſm, with ſimilar apices, may ariſe in many ways: thus to the cube, indicated by the letters A B C D, fig. 15. let there be applied on each ſide the quadrangular pyramids A B E, and D C F; and we ſhall have the priſm required. In this way common ſalt ſometimes, though very ſeldom, acquires an apex (*k*). Let us ſuppoſe applied to one or both apices of the octaedron A C B D, fig. 16. a hollow pyramid a d b, but ſimilar and equal to the fundamental figure; and the ſame

(*k*) Capeler, *Prod. Cryſtallographiæ*, t. iii. fig. 2.

figure will be produced: however, I muſt confeſs, that I have never ſeen alum priſmatic, though often conſiſting of octaedra imperfectly joined, fig. 17. A four-ſided pyramid may be compoſed of four tetraedra, and conſequently a cube of 24; and it has alſo a double apex of 32. Thus we have a new conſtruction, which undoubtedly ſometimes takes place; for, as I have already ſaid, arſenical cryſtals take ſometimes the tetraedral, ſometimes the octaedral form, which may therefore eaſily be mutually changed.

It is with leſs facility that hexagonal priſms are formed of ſuch pyramids as have the ſame number of ſides, unleſs tetraedral be admitted. In fig. 18 four hexagonal pyramids and ſix tetragonal meet; the firſt are eaſily reſolved into ſix, and the latter into four tetraedra (fig. 19.); forty-eight of which conſequently make up the whole maſs, ſuppoſing this to be the method followed by nature. I have no doubt that this conſtruction is probable, on many accounts, for it requires only the moſt ſimple elements, and ſuch as are conformable to the figures of all cryſtals. That tetraedra, adapted to this purpoſe, have ſometimes diſſimilar and unequal ſides, makes not againſt the ſuppoſition: but what is moſt to the purpoſe, is, that ſometimes ſuch tetraedra are employed without the ſmalleſt doubt. All theſe circumſtances are of no ſmall weight; but

but ſo long as no traces of tetraedra are to be found among the pyramids of common ſalt, the laws of ſound reaſoning forbid us to draw any general concluſion : it is better to purſue actual obſervations than fictions, however ingenious : better cautiouſly to examine the myſteries of nature, than haſtily and preſumptuouſly to decide. I am perfectly certain that nature does frequently employ pyramids in this operation : it remains for future experiments to determine whether this be always the caſe, &c. I have been intent upon the mechaniſm of the concretion during a very aſſiduous examination of ſalts. I have related the principal phænomena which appeared, and at the ſame time have interſperſed various obſervations ; wiſhing that more ſagacious obſervers may hereafter completely diſcover the ſyſtem of corpuſcular attraction, which is particularly obvious, and as it were palpable, in cryſtallization.

§ v. *Whether Cryſtallization neceſſarily implies the Preſence of a Salt.*

Some of the moderns, conſidering that many ſalts affect an angular form, and frequently one of a conſtant and permanent kind, ſuppoſed this property to belong excluſively to ſalts ; and when they met with any bodies ſimilarly figured, they attributed this figure to a ſalt which they ſuppoſed

 concealed

concealed in that body :—what judgment we are to form of this opinion, will appear from the following confiderations.

(A) As cryftallization is the effect of attraction; and as all other matters, as well as falts, are fubject to the laws of that attraction, we are not authorized to confider the regular and fymmetrical figure as peculiar to faline bodies, although the affumption of fuch figure be more readily and frequently exercifed by them, as being foluble in water. But cryftals are produced by fuch other methods as can fufficiently divide and difengage the integrant parts (§ IV. B and C.)

(B) Upon examining falts it will plainly appear, that thofe which are moft fimple, and poffefs the faline properties in the moft eminent degree, coalefce with the greateft difficulty. The truth of this affertion is evinced by the mineral acids and the cauftic alkali, which, when pure, and freed as much as poffible from every heterogeneous matter, it is fcarce poffible to reduce to the form of cryftals.

(C) The fimilarity of forms in cryftals does not depend upon the acid; for, to pafs over many other examples, the prifmatic and quadrangular nitre, which are formed by the fame acid, yet conftantly differ in figure :—neither is the bafe fufficient; for the vegetable alkali, as well as the mineral, faturated with marine acid, generates cubic cryftals. The external appearance therefore

fore depends upon the menſtruum and the baſe jointly:—we are not, however, from thence to conclude that there is preſent a neutral or middle ſalt, whenever the figure of ſuch a one is diſcoverable. Not the ſmalleſt particle of alum is found in lead or nickel united with nitrous acid, although both theſe compounds yield octaëdral cryſtals.

(D) A great variety is obſerved in cryſtals, though the matter remains the ſame: I have already ſhewn this to be the caſe with calcareous cryſtals (§ 11). In the family of the pyrites, cubes are ſometimes found ſtriated in a ſingular manner, ſo that the lines of one ſide are perpendicular to thoſe which diſtinguiſh the four adjacent ſides (fig 13); but among theſe are alſo found tetraedra, octaedra, dodecaedra, and icoſaedra; ſo that in this caſe all the regular ſolids are found.

(E) Finally, a very great number of cryſtals are either totally deſtitute of any thing ſaline, or elſe poſſeſs it in ſuch ſmall quantity that no experiments hitherto tried have been able to diſcover the ſmalleſt ſenſible traces of it. I have in my poſſeſſion hexangular priſms of mica, which are compoſed of parallel lamellæ; the elementary ſpiculæ of which are diſpoſed in a ſingular manner (fig. 14): gems, granites, ſchoerls, and other earthy bodies, are frequently found figured, though analyſis can diſcover nothing ſaline. The ſame is true of gold, ſilver, and the other native metals; as alſo gold, ſilver, lead,

lead, tin, bifmuth, and zinc, united with mercury, of which all put on regular forms, according to the quantity of the mercury (*l*).

If we have recourfe to the fuppofition of an hidden faline fubftance, which cannot be difcovered by art, it will furely be unreafonable to attribute to fuch a principle fo great a power as that of arranging the particles in the order neceffary for cryftallization; a caufe beyond queftion unequal to the magnitude of the effect: for how is it poffible that a faline matter, the prefence of the fmalleft atom of which cannot be difcovered by the moft delicate tefts, fhall in pure water have yet power to effect the icy cryftallization with fuch force as to overcome the moft powerful obftacles? How can a faline matter, which by no teft can be difcovered, have power, in an amalgam of gold, to arrange the ponderous particles of both metals in a particular manner? What falt is able to form the ftellated regulus of antimony? what the hexagonal lamellæ of mica?—Thefe obfervations will fuffice for thofe who wifh to build their knowledge upon the folid bafis of experiment—to thofe who indulge hypothefes, the experience of centuries will convey neither conviction nor information.

(*l*) *Mem. de Chémie*, par M. Sage.

DISSERTATION XIII.

OF

SILICEOUS EARTH.

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§ I.

WE find it long ſince obſerved by Theophraſtus the Ereſian (*a*), that a moſt excellent glaſs might be formed of that ſpecies of ſtone which ſtrikes fire with ſteel, and is called flint; and hence perhaps it was, that all ſtones which joined to alkaline ſalts can form a glaſs, were called vitreſcible. There are ſome, indeed, who explain this denomination in another way, and conſider it as indicating only the property of melting by means of fire without

(*a*) De Lapid. 84. So Pliny, " *Auctores ſunt, in India & cryſtallo fracto fieri (vitrum) & ob id nullum comparari Indico.*

addition.

addition. But as vitreſcible earths, when alone, are very refractory, the former account ſeems to be more probable.

In the preſent century thoſe ſtones which had before been called vitreſcible, were called ſiliceous by Mr. Pott, and after him by Mr. Cronſtadt. The celebrated chemiſt of Berlin, above-mentioned, ſeems to have been the firſt who (in 1746) eſtabliſhed the genuine criteria of theſe ſtones; at leaſt he determined them more accurately than any perſon before his time, and, after aſtoniſhing labour, diſcovered their habits, in mixture with the various earths and ſalts (*b*). Stones which are ſo hard as to ſtrike fire, are commonly called ſiliceous; but this property depends more upon the connection of the particles than the nature of matter itſelf.

Glauber (*c*), if I miſtake not, was the firſt who gave a clear deſcription of the liquor of flints; though J. B. Van Helmont, in ſpeaking of glaſs, aſſerts that if it be made with too much alkali it deliqueſces; and that, by means of an acid, it precipitates a quantity of ſiliceous earth equal to that which had been uſed in the making of the glaſs (*d*).

Siliceous earths have been but little examined with regard to their principles and compoſition. Geoffroy aſſerts, that by repeated calcination they may be reſolved into abſorbent earth (*e*). Neuman relates, that

(*b*) Gethogeogn. (*c*) Furn. pars 2.
(*d*) De Terra. (*e*) Mem. Par. 1764.

he

he obtained from them, by diſtillation, an oily empyreumatic ſubſtance, which made ſyrup of violets red, and, upon addition of concentrated vitriolic acid, diffuſed the ſmell of volatile ſpirit of ſalt (*f*): but Ludovici, upon diſtillation, obtained, as he relates, from a pound of ſiliceous earth, two drachms of an acid liquor with a ſulphureous odour, and the reſiduum by elixation communicated a ſtyptic taſte to water, from which, by alkali of tartar, a tartar was precipitated (*g*). Carl alſo obtained an acid liquor of the ſame kind (*h*).

Others ſay that they have obtained it ſublimed with ſal ammoniac, of a variegated colour, together with a green liquor. Neuman (*i*) aſſerts, that he was able, by means of vegetable acids, to extract a portion of lime from mountain cryſtal, but not from quartz; that the acids acted more powerfully upon the cryſtals when calcined; that of one drachm of the ſofter flint 22 grains were diſſolved by concentrated vitriolic acid, and by the diluted acid 20; by marine acid 15; by nitrous acid 16; by vinegar 10; but that from the harder flints which ſtrike fire, nothing was extracted (*k*).

Glauber (*l*) imagines, that on diſtilling powdered quartz or flint with two or three

(*f*) Prælect. Chem.
(*g*) Eph. N. C. Dec. an. 6 & 7.
(*h*) Juncker Conſp. Chem. t. i.
(*i*) L. c. (*k*) L. c. (*l*) L. c.

parts

parts of alkali of tartar, it foams out of the retort, and diffuſes an acid liquor like to marine acid in ſmell, but differing from it in taſte, and other properties; this liquor he thinks is derived from the alkaline ſalt, though Stahl aſcribes it to the ſiliceous matter.

Pott aſſerts, that the earth precipitated from liquor of flints (*m*) by acids, is perfectly ſoluble in them, and that with vitriolic acid it produces alum (*n*); this was afterwards aſſented to by Beaume (*o*), but is very juſtly denied by Cartheuſer (*p*), Scheele (*q*), and others (*r*). The celebrated J. C. F. Meyer obſerved (*s*), that liquor of flints, dilated with a certain quantity of water, bore acids without precipitation: this is a remarkable phænomenon, which will be explained hereafter.

Finally, the celebrated Dr. Prieſtly, who is making attempts to reſolve all bodies into air, having expoſed ſiliceous powder, moiſtened with acid of nitre, to an intenſe heat, obtained, in an apparatus prepared for the purpoſe, firſt aerial acid, then nitrous air and common air, and laſtly air of remarkable purity; and theſe he obtained in the

(*m*) Contra Ellerum.
(*n*) Lithog. p. 3. præf.
(*o*) Man. de Chémie.
(*p*) Miner. abh. theil.
(*q*) Act Stock. 1776.
(*r*) Diff. couronnée par la Soc. Montp.
(*s*) Beſchaft. der Berl. Geſellſch.

ſame order ſeveral times, by moiſtening the maſs afreſh (*t*).

The illuſtrious Count de Buffon conſiders clay as flint minutely divided, and on the contrary flint as clay very much condenſed; how juſtly, will appear from the ſequel. We ſhall paſs over the looſe conjectures of authors concerning the origin of this earth; conjectures which are only built upon the places where it is found, its ſituation, or other circumſtances often very trifling; and only obſerve, that pure ſiliceous earth is generated in the diſtillation of the mineral fluor with vitriolic acid; a ſubject which has been ſo ably handled by Mr. Scheele. How this geneſis of ſiliceous earth is effected we ſhall enquire hereafter in its proper place.

§ II. *Criteria of Siliceous Earth.*

In order to avoid all future ambiguity, it is neceſſary to begin by defining what is underſtood by the term *ſiliceous earth*. It is that earth which is precipitated by acids from liquor of flints, and which, even though the acid be ſuperabundant, remains undiſſolved. Clay is alſo diſſolved by alkaline ſalts, and is alſo precipitated by acids; but is again taken up by the acid, if ſufficient quantity be added. I ſhall therefore

(*t*) Experiments on Air.

paſs

paſs over the latter, and go on to mention ſome of the principal properties of the former earth, ſuch as are often uſeful to diſtinguiſh it from others; but I ſhall only take notice of a few properties which may ſerve as criteria. The following are the moſt remarkable, and ſuch as ſerve to diſtinguiſh it very eaſily from all others.

The ſiliceous earth is not acted upon in the uſual way by any acid, that of the mineral fluor excepted.

But it may be diſſolved in fixed alkalis, either by the dry or the humid way; and in the former caſe, with violent efferveſcence, runs into a glaſs which is ſo much the harder as the ſiliceous earth, by means of a due degree of heat, conſtitutes a larger proportion of the whole maſs. With $\frac{1}{2}$ alkali a clear and very hard glaſs is obtained; but with double or triple the quantity, a vitrified maſs, which attracting the moiſture of the atmoſphere, deliqueſces ſpontaneouſly.

It cannot be fuſed when alone by the moſt violent ordinary fire, but is diſſolved by the addition of borax, without efferveſcence; it is alſo taken up by the microcoſmic ſalts, though far more ſlowly and ſparingly.

§ III. *Its Habits with Acids.*

The earth newly precipitated from liquor of flints, when waſhed and ſtill wet, cannot be diſſolved in the common acids, ſuch as vitriolic

vitriolic, nitrous, and marine, although in that ſtate its ſurface is increaſed as much as poſſible; and although to each part of earth 1,000 of concentrated acid were added, and boiled for an hour, the ſiliceous maſs, when afterwards collected and waſhed, remains of the ſame bulk as before, and the menſtruum is not impregnated with the ſmalleſt particle.

This is ſtrictly the caſe with regard to pure ſiliceous earth; but if three parts of alkaline ſalt be melted in a common crucible with one of quartz, the ſalt diſſolves at the ſame time about 0,07 its own weight of the argillaceous matter of the veſſel, which are precipitated by acids, and re-diſſolved upon adding a ſufficient quantity of the acid menſtruum: but it is obvious that in this caſe the argillaceous clay is a foreign admixture, and by no means a conſtituent part of the liquor of flints. If the operation be performed in an iron veſſel there will be no argillaceous earth obtained, however often the experiment be repeated. There is certainly a portion of clay, though extremely ſmall, which is always found in quartz itſelf: but the ſiliceous earth precipitated from liquor of flints, and freed by an acid from all heterogeneous matter, though afterwards repeatedly fuſed with fixed alkali in an iron veſſel, will not yield even the moſt minute portion of clay; theſe different caſes ſhould be well obſerved, leſt we be led into an erroneous belief of the converſion of ſiliceous into argillaceous earth.

We ſhall hereafter (§ IV. C) ſee that ſiliceous earth may, by certain management, be diſſolved in acids.

(B) The fluor acid is never got entirely free from ſiliceous earth; ſo that, being more or leſs loaded with it, it muſt of courſe be found leſs active. Here it is proper to obſerve, that ſuch earth is called ſiliceous as is either collected in the recipient during the diſtillation of fluor acid, or is afterwards depoſited by that acid: the reaſon of this denomination will appear hereafter (§ V).

In order to examine the ſolvent power of this acid, in the year 1772 ſome quartz very finely powdered was put into a bottle which contained $\frac{1}{8}$ of a kanne of the acid; the bottle was then ſlightly corked, and ſet by in a corner of the room; two years afterwards it was examined, and, the liquor having been poured out, there were found concreted at the bottom of the veſſel (beſides innumerable ſmall priſmatic ſpiculæ) thirteen cryſtals, of the ſize of ſmall peas, but moſtly of an irregular form; ſome of them reſembled cubes whoſe angles were all truncated, ſuch as are often found in cavities of flints. Theſe ſiliceous cryſtals, the firſt perhaps that were ever produced by art, were indeed hard, but not comparable with quartz, except in eſſential properties, in which they perfectly agreed. Poſſibly the length of a century may be be neceſſary for them to acquire by exſiccation a ſufficient degree of hardneſs. The bottle itſelf, as far as the liquid had reached, was found covered on the inſide with a very thin ſiliceous pellicle, which was ſcarcely viſible, but ſeparated on breaking the bottle; it was extremely pellucid, flexible, and exhibited the priſmatic colours.

Theſe phænomena ſhew that much ſiliceous matter is diſſolved and ſuſpended: whether any of the quartz was taken up is uncertain, but it appears probable that little or none was diſſolved in this experiment, ſince, by the help of heat, during the diſtillation the acid had previouſly taken up ſo much ſiliceous earth, that upon ſlow evaporation it was unable to retain it: hence appears the origin of the cryſtals and the pellicle; and hence appears the cauſe which impedes the action of fluor acid upon flint; namely, that the acid obtained in the ordinary way is already ſaturated with it.

Flint diſſolved in fluor acid is moſt completely precipitated by volatile alkali; and by this method it is found that one part of flint is contained in 600 of the acid ſo much diluted that its ſpecific gravity is only 1,064. This precipitate poſſeſſes all the criteria of pure flint (§ 11.): but that which is precipitated by fixed alkali, either vegetable or mineral, does not exhibit a pure ſiliceous matter, but a triple ſalt of a peculiar kind, compoſed of ſiliceous earth, fluor

 acid,

acid, and fixed alkali, which diſſolves, tho' difficultly, in warm water (eſpecially that which is made with vegetable alkali), but is eaſily decompoſed by lime-water, and lets fall the mineral fluor regenerated; ſo that this precipitate muſt be well diſtinguiſhed, and not confounded with that which is precipitated by volatile alkali.

§ IV. *Its Habits with alkaline Salts.*

In the humid way (by boiling) fixed alkaline ſalts attack the ſiliceous earth, but not unleſs it be very finely comminuted, and newly precipitated from liquor of flints. Alkali of tartar, ſpontaneouſly diſſolved by attracting moiſture from the atmoſphere, by boiling takes up about one-ſixth of its own weight; and the liquor, upon cooling, forms a jelly, although at firſt diluted with ſixteen times its weight of water. This ſolution is effected by the cauſtic portion which is always preſent in this alkali, for when the alkali is aerated it rejects the earth; nay, upon the addition of aerial acid, even the cauſtic alkali depoſits the earth.

The volatile alkali, even though cauſtic, has no effect in this way.

(B) In the dry way fixed alkalis attract ſiliceous earth, inſomuch that one-half its weight of theſe ſalts melt with it into a glaſs tranſparent, hard, and firm; which is not

not the caſe with any other earth yet known. During the conjunction a violent efferveſcence is obſerved; but if the vapour which aſcends be collected, it is found to conſiſt of nothing but water and aerial acid.

If the proportion of alkali be greater, a glaſs is obtained more ſoft and lax; and if it be increaſed to double or triple, the glaſs attracts the moiſture of the air, and is reſolved into a liquor, which (from the ſiliceous earth) is called liquor of flints.

(c) This liquor is precipitated by all acids, as the alkali unites to them more readily than to the ſiliceous earth, which (being thus deprived of its menſtruum) falls to the bottom. The ſiliceous matter, thus precipitated, is of an exceeding looſe and ſpongy texture, and is ſwelled by water ſo much that its bulk when wet exceeds its bulk when dry at leaſt twelve times: nor does it contract more in the water, though ſuffered to reſt in it a long time. Hence the liquor of flints may, by time and a quantity of precipitant properly adjuſted, be eaſily converted into a jelly, eſpecially if diluted with four or eight times its weight of water: for in that caſe the fluidity is ſo regulated that the precipitant can eaſily ſeparate the ſiliceous particles, and the particles ſo ſeparated can at once occupy the whole maſs; but if an overproportion of water be uſed (for inſtance, twenty-four times the weight) in this caſe the liquor remains limpid, al-

 though

though ſo much acid be added as is more than ſufficient to ſaturate the alkali. This is a remarkable phænomenon, the rationale of which, if I miſtake not, is the following: —

The ſiliceous particles are removed from each other very much by the diluting water; or rather, being diffuſed through ſo large a maſs, are more rare. Now by every diminution of bulk the ſurface is encreaſed, and, together with that, the contact of the ſurrounding fluid; hence, although the ſiliceous earth, by its ſpecific gravity, ſhould fall to the bottom, yet in the preſent caſe it is not able to overcome the reſiſtance occaſioned by friction, for greater force is requiſite to open the way downwards than is ſupplied by the difference of ſpecific gravities: the ſiliceous molecules therefore remain ſuſpended in the fluid at the ſame time inviſible, both on account of their tenuity and their tranſparency: but if the bulk of the fluid be diminiſhed by evaporation, eſpecially by boiling, which at once diminiſhes its gravity and tenacity, the ſiliceous matter is ſeparated.

Liquor of flints is alſo decompoſed by too great a quantity of water; for by this the efficacy of the alkaline menſtruum is ſo much diminiſhed, that it is no longer able to keep the ſiliceous matter diſſolved, and it is alſo partly ſaturated with the aerial acid inherent in the water.

(D) It

(D) It may ſeem extraordinary, that fluor acid ſhould precipitate liquor of flints, as this acid ſtrongly attracts the ſiliceous earth; but it is to be obſerved, that it ſtill more ſtrongly attracts the alkali: beſides, in this caſe, it is not a pure ſiliceous matter which is precipitated, but an earth, combined both with acid and alkali, as was before obſerved (§ III. B). But there is ſome difference in the two caſes, for in this inſtance the acid and the alkali, both loaded with ſiliceous earth, meet one another: while, therefore, the acid is ſaturated with alkali, it alone depoſits a quantity of ſiliceous matter, this depoſition therefore may all be diſſolved by moderate heat in a ſufficient quantity of water; and when expoſed to the flame by a blow-pipe, readily fuſes, exhibiting a pellucid little ſphere, which, upon loſing its fluidity, grows opaque and white. The precipitate from liquor of flints by fluor acid has the ſame properties, but ſomewhat leſs ſolubility and diſpoſition to liquefy, doubtleſs occaſioned by a larger proportion of ſiliceous earth: both theſe ſaline precipitates contain the fluor acid, which is diſcharged upon the addition of the vitriolic, and the ordinary phænomena exhibited. To an inattentive obſerver it will appear, that in this caſe we have the fluor mineral accompanying the acid; but a more accurate examination will detect this error: for the reſiduum, after the diſtillation of fluor, always contains gypſum, ſome-

 times

times mixed with alum and flint, whereas here nothing remains but vitriolated alkali, intermixed with flint. Hence we ſee how much caution and vigilance is neceſſary to prevent us from embracing error inſtead of truth.

(E) The aerial, which is the weakeſt of all acids, yet precipitates liquor of flints; and that quickly and copiouſly, if it be ſuddenly added, and in ſufficient quantity; but it is not neceſſary to mix them, it is ſufficient if liquor of flints be expoſed to the atmoſphere, either open or imperfectly ſhut, for then the ſubtile precipitant is attracted, and the fluid depoſited very ſlowly, in proportion as the alkali is aerated.

§ V. *Siliceous Earth poſſeſſes ſomewhat of a ſaline Nature.*

The proof of this is not to be drawn from the cryſtalline figures which ſiliceous ſtones often aſſume (for this is a property not peculiar to ſalts) more convincing arguments may be drawn from its compoſition and its ſolubility.

(A) In order to underſtand the geneſis of ſiliceous earth, as far as it has yet been poſſible to penetrate that myſtery, let us attentively conſider the diſtillation of fluor acid: the phænomena of this operation are entirely of a new ſpecies, and, to be well underſtood, require the greateſt ſkill and attention.

Let

Let 100 parts of pulverized fluor be put into a glaſs retort, and through a tube 50 parts of highly concentrated vitriolic acid be poured in; immediately a ſenſible degree of heat is found to ariſe in the maſs, and a vapour of a moſt penetrating odour is produced; let 100 parts of diſtilled water be kept in the recipient; let a gentle heat be applied, which is to be raiſed by degrees, until the bottom of the retort becomes at laſt red: during this time the body and neck of the retort are incruſted by a white matter, and the ſurface of the water in the recipient is covered with a cruſt of the ſame colour. When the veſſels cool let the white matter in the recipient be firſt collected, well waſhed and dried; — it is found to be equal to about one part and a half of the maſs ſubjected to the diſtillation.

This is very light and ſpongy; not only inſoluble in water, but in the ſtrongeſt acids; very refractory in the fire when alone; with one half of fixed alkali it yields a tranſparent and ſtrong glaſs, but with three times that quantity produces a ſaline maſs, which deliqueſces, and becomes liquor of flints: in a word, it exhibits all the criteria of a true and pure ſiliceous earth; and, on expoſition to the focus of a burning mirror, agrees with that earth, as the celebrated Macquer experienced with a ſmall portion of this ſiliceous powder, artificially prepared in the laboratory at Upſal.

Besides the siliceous earth above mentioned, which is chiefly formed in the recipient, a white pellicle adheres to the neck and body of the retort; this, upon examination, is found to be nothing but the mineral fluor, more or less deprived of phlogiston, enveloped even externally by its own acid, but containing little or nothing of siliceous earth: it therefore easily fuses, upon exposure to the blow-pipe, and, upon addition of vitriolic, the fluor acid is expelled.

If the distillation be performed with an equal, a double, or a still greater quantity of vitriolic acid, the same phænomena take place, but with greater vehemence; more of the fluor is volatilized; and it sometimes even passes over into the receiver: the glass is almost always corroded, and, if thin, perforated. The water in the receiver, which by the first method contains a pure fluor acid, is in the latter more or less mixed with the vitriolic. The elastic fluid, which is generated, and may be collected in mercury, does not proceed entirely from the fluor alone, but is also mixed, more or less, with something proceeding from phlogisticated vitriolic acid; so that a wrong judgment is formed of the whole elastic fluid, from that by which it is adulterated.

The mineral fluor, distilled in the same manner with four times its quantity of nitrous or marine acid, yields the same product;

duct; but a smaller quantity of fluor is volatilized, less fluor acid is extricated, and less siliceous earth is produced: the water in the recipient, besides the fluor acid, always contains somewhat of the decomposing acid; nay, the acids of the vegetable and animal kingdoms produce the same effect, but in a smaller degree. The siliceous earth is then generally found to be wanting in the receiver; and from the weakness of the decomposing acid a smaller quantity of fluor acid is expelled, sometimes indeed so small, that the whole of the earth produced is dissolved, but it can again be separated by volatile alkali. According to the new table of attractions of the fluor acid it has a greater affinity with lime than the nitrous, marine, and other acids have; and this is agreeable to experience; but when heat is applied the more volatile, though it be the stronger acid, must yield to the more fixed: the fluor obstinately resists fire when alone, but by means of another acid a small degree of heat is sufficient to volatilize it. The mineral fluor, though often heated and extinguished in water, yet, when afterwards distilled with vitriolic acid, yields its acid in the usual way.

Most of these phænomena are easily understood, upon the supposition that the fluor acid, united with lime, constitutes the fluor itself; that it is very volatile; and that when expelled it elevates some of the fluor

to

to a certain height; and that this height is the greater in proportion as the expulſion of the acid is quicker. It has alſo been demonſtrated before (§ 111.) that when hot it attracts ſiliceous earth very powerfully; and this without doubt is the reaſon why glaſs, which is always partly compoſed of ſiliceous earth, is corroded.

The principal objections which in this buſineſs obſcure the truth, and diminiſh the validity of our concluſions, though already mentioned, ſhall here be ſet in view together, as they throw ſeveral obſtacles in the way of our reſearch. Theſe are, 1ſt, the immoderate quantity of vitriolic acid: if the fluor acid only be required, one-half the weight of the decompoſing acid is ſufficient; if a perfect decompoſition of the fluor, there is need of four times the quantity, and in general we cannot err by the largeneſs of the proportion. 2d, By want of water in the receiver the glaſs veſſels are more corroded, and the elaſtic vapour, which cannot be condenſed into a liquid form without it, now for the moſt part burſts forth, being only confined by the portion of water which adheres to the vitriolic acid. Great obſcurity ariſes from, 3d, confounding things that ought to be diſtinguiſhed from each other: the volatilized fluor, the pure ſiliceous earth found chiefly in the receiver, the precipitates from the fluor acid by fixed or volatile alkali, are all ſubſtances that ſhould be carefully

fully diſtinguiſhed. In like manner the elaſtic fluid, elicited from the mineral fluor by a proper quantity of vitriolic acid, is very different from that obtained by the ſame acid phlogiſticated.—But let us return to our proper buſineſs, for all the properties of fluor acid do not belong to the preſent enquiry, which only regards the ſiliceous earth. I thought it however neceſſary to mention ſuch of them as lead directly to the end propoſed.

The queſtion then is, whence the ſiliceous earth which occurs in the operation is derived? whether it is extracted from the mineral fluor, and elevated by the fluor acid, or whether it is extricated from the glaſs veſſel itſelf?—many circumſtances, hereafter to be mentioned, are repugnant to each of theſe opinions; and the experiments which have hitherto been inſtituted rather ſeem to indicate that this ſubſtance is actually produced during the operation.

1ſt. That the ſiliceous earth does not owe its origin to the mineral fluor is eaſily ſhewn: for although this fluor ſometimes contains ſiliceous earth, yet this does not always happen; and nevertheleſs as large a produce of that earth is had from that which is entirely deſtitute of ſiliceous matter as from that which contains it. The green earth of Garpenberg, for inſtance, is in general entirely free from ſiliceous earth, and therefore may be totally diſſolved, either in nitrous

nitrous or marine acid. This ſolution, upon the addition of cauſtic alkali, precipitates pure fluor, totally unchanged; but the mild alkali, by means of a double elective attraction, precipitates aerated lime: — on the addition of vitriolic acid gypſum is formed.

2d, As the glaſs is corroded by the vapour of the fluor acid, at firſt ſight it appears not an improbable conjecture, that the ſiliceous earth which appears is produced from thence; but we muſt obſerve, that by employing a ſmall quantity of fluor and a gentle fire, the ſiliceous earth may be obtained without any corroſion; beſides, the corroſion bears no proportion to the quantity of ſiliceous earth.

3d, That the ſiliceous earth, diſſolved or volatilized by the acid, paſſes over from the retort into the receiver, is an opinion contradicted by a variety of experiments;—if, in place of water, alcohol be put into the receiver, the acid is collected in it, but no ſiliceous powder, which, on the hypotheſis of volatilization, ought to be found. Of this circumſtance we ſhall ſpeak more at large hereafter.

But the powder formed in the receiver, well waſhed, and diſtilled with vitriolic acid, is not elevated, much leſs does it paſs over into the receiver, and it yields no fluor acid. Leſt it ſhould be ſuſpected that this is owing to a deficiency of the phlogiſton neceſſary

to

to volatilization, let a few drops of olive oil be added, and from hence, upon the application of heat, a white ſmoke will ariſe; and if the end of the retort's neck be plunged in water, a white ſquamous membrane is generated on the ſurface. This would at firſt appear a proof of the volatilization of ſiliceous earth, but upon examination the error is diſcovered; this membrane being found to be nothing more than a ſebaceous matter diſcharged from the oil by means of the acid, in a ſtate of coagulation, and carried up by the ſmoke; and the ſame kind of membrane is produced, if nothing be uſed but the oil and the acid. If the fluor acid be nothing more than a modification of the vitriolic (a queſtion which muſt be decided by future experiments) the change produced in this caſe is a very ſingular one, and muſt be totally different from that occaſioned in general by phlogiſton: in the mean time it cannot with juſtice be denied, that the fluor acid is contained in the fluor itſelf; for if the fluor acid be mixed with lime-water, the mixture immediately becomes turbid, and a powder is depoſited, which, waſhed and dried in a certain degree of heat, becomes phoſphoric; diſtilled with vitriolic acid it yields fluor acid and ſiliceous earth, and agrees in all reſpects with the mineral fluor. On what pretext then can it be denied that the acid which was juſt now mixed with it is preſent in it? The mineral fluor is therefore lime ſaturated

with

with fluor acid. Sometimes, indeed, there is preſent a little clay and flint; theſe, however, are not always found, but only caſually, and they by no means conſtitute the eſſence of the ſubſtance. The greateſt quantity that I have yet found was four grains of clay in an ounce of mineral fluor, that is $\frac{1}{120}$. There is alſo ſometimes a ſmall portion of marine acid, which has not yet been found to exceed five grains in an ounce of mineral fluor.

Upon conſidering theſe circumſtances, which are not the reſult of a ſingle experiment ſlightly conſidered, but of diſtillations frequently repeated and accurately examined, it ſeems neceſſary to have recourſe to a new production, a thing which indeed ſhould never be attempted but upon the beſt grounds.

In general we can no other way conceive the nature of fluid bodies than by conſidering them as congeries of ſolid particles, which are ſo minute that when combined with a certain quantity of heat, they acquire that degree of mobility which is ſufficient to preſerve a level ſurface; which level, if by any means diſturbed, is immediately recovered. Now the primary aqueous elements, united while in a fluid ſtate with fluor acid, ſcarcely contract a firm texture, but yield a dilute acid, a circumſtance which takes place with reſpect to other acids; but upon the application of heat they put on the form of an elaſtic vapour, and in in this ſtate meeting with the vapour of the fluor acid, it is extremely probable that by their union they form the white powder above-mentioned: it is certain that when liquid they both offer a much ſmaller ſurface of contact than when in the ſtate of vapour; and this difference in the latter caſe occaſions a very cloſe union, which in the former can ſcarce poſſibly take place, on account of the ſmall ſurface of contact.—If mineral fluor be treated with highly concentrated vitriolic acid, unleſs there be water in the receiver, the elaſtic vapour can ſcarcely be condenſed into a liquid form, but for the moſt part penetrates the luting, and corrodes the glaſs in a more than ordinary manner: by means of the water, which ſtill adheres to the vitriolic acid, a ſmall quantity of liquor will be formed; *viz.* as much as eſcapes being condenſed into an earth. The acid vapour itſelf, collected in mercury, yields an elaſtic fluid not condenſible by cold; water abſorbs this acid fluid, but watery vapour coagulates it. Hence we may underſtand why pulverized mineral fluor, when expoſed to a digeſting heat in a cloſe cucurbit, with twice its quantity of concentrated vitriolic acid, covers wet bodies, ſuſpended over the maſs, with a white powder, while dry bodies expoſed in the ſame way do not contract a particle of powder; as alſo, why the fluor acid, often diſtilled with water, may be totally converted into ſiliceous earth. There is therefore neceſſary for this concretion (beſides the hot acid vapours) water, alſo converted into vapour; and the coagulation is performed with great difficulty within the maſs, but very eaſily at the ſurface, which, while fluid, is in a perpetual ſtate of evaporation.

But whatever be the cauſe of this ſingular union (which is highly deſerving of accurate examination) it is at leaſt certain that the fluor acid makes a part of it: ſuch a combination is very analogous to the neutral and middle ſalts, and therefore is not without reaſon conſidered as partaking of a ſaline nature, although ſcarcely ſoluble in water, in the ſame manner as gypſum, or as the mineral fluor (which conſiſts of fluor acid ſaturated with lime, and is totally inſoluble in water) is acknowledged to approach to the nature of middle earthy ſalts.

(B) Let us now ſee whether ſiliceous earth be totally inſoluble in water: That certain waters contain ſiliceous earth is beyond a doubt; but it is probable that it rather remains ſuſpended in them by means of the ſubtlety of its parts, than in virtue of a true ſolution.

It is known that water becomes the more capable of diſſolving bodies, in proportion to its degree of heat; but in open veſſels it is incapable of receiving a degree of heat greater than that of the boiling point, or 100°. Siliceous earth, expoſed in water to a boiling

ing heat for ever ſo great a length of time, is ſcarce ſenſibly diminiſhed, ſo that by this experiment it ſeems totally inſoluble; but we cannot thence conclude that it is able to reſiſt a greater heat. The efficacy of Papin's digeſter has ſhewn, that many bodies may be diſſolved which totally reſiſt boiling in open veſſels: at the ſame time it muſt be confeſſed, that no one has yet tried ſiliceous earth in this way; ſo that we ſhould be entirely ignorant what would be the event, had not nature herſelf ſpontaneouſly aſſiſted our ignorance and ſloth.

Thus, at Geyſer in Iceland there ſprings up a hot water, which upon cooling depoſits ſiliceous earth, and of this very matter has formed for itſelf a crater, in which columns of water of a ſtupendous bulk, after they have been thrown to the height of 90 feet and upwards, fall, and are again received. The heat of the water during the exploſion cannot indeed be meaſured; but after it has riſen and fallen through a ſtratum of air 90 feet thick, it raiſes the thermometer to 100°; which evidently ſhews that the heat in the bowels of the earth muſt be vaſtly more intenſe; and this we ſhall ceaſe to wonder at, when we conſider that in this caſe the ſubterraneous fire acts upon the water in caverns cloſed up by very thick ſtrata of ſtones, an apparatus far more effective than Papin's digeſter. The crater undoubtedly was at firſt formed, and is daily ſtrengthened, by ſiliceous earth, which quits the menſtruum on its being cooled, falls down, and being in ſomewhat like a ſoft ſtate, concretes (*o*).

From what has been ſaid it abundantly appears, that ſiliceous earth is of a ſaline nature, but differs ſo much in degree of ſolubility, that our artificial limits oblige us to refer it to the earths.

§ VI. *Whether Siliceous Earth be a primitive Earth.*

Thoſe earths are called primitive which cannot artificially be reſolved into ſuch as are more ſimple; derivative, thoſe which are compoſed of two or more primitive earths intimately united: the queſtion is then, to which of theſe claſſes the ſiliceous earth may with moſt propriety be referred?—If the queſtion was, whether ſiliceous earth be altogether ſimple and homogeneous? the proper anſwer would be in the negative; for, upon conſidering the very probable circumſtances above related, concerning the origin of this earth, it appears plainly to conſiſt of two principles, namely, the fluor acid, and ſomewhat derived from the water. It cannot therefore be conſidered as ſimple and homogeneous; but inaſmuch as we are ignorant of the true nature of the primary ſtamina of

(*o*) Vid. De Product. Vulcan.

5 water,

water, and as it does not appear that any of the other primitive earths, ſuch as lime, terra ponderoſa, magneſia, or pure clay, are derived from the genuine ſubſtance of water, it appears that in mineralogy the ſiliceous earth may properly be conſidered as primitive, until by apt experiments, both analytic and ſynthetic, it be demonſtrated that the baſe of this earth entirely agrees with ſome one of theſe above mentioned: when this is done, it may properly be referred to the derivatives, but not before; in the interim, naked conjectures and fallacious obſervations are not by any means to be confided in. It muſt be allowed that, to ſyſtem builders, it will appear more ſimple to conſider all earths as of the ſame ſpecies, with a very few modifications; but it ſhould be remembered, that he who pretends *a priori* to judge of the moſt compound body in nature, ought firſt to be acquainted with the whole ſtructure and œconomy of nature.

Some perſons, obſerving that clay acquires by fire a flinty hardneſs, think that the principles of both are the ſame; an opinion which would be eſtabliſhed beyond doubt, if ſiliceous earth, diſſolved in fixed alkali, could, by means of the vitriolic acid, form alum, which has been attempted by certain moderns: but this hypotheſis, when put to the teſt of experience, falls to the ground; for the pure clay is all converted into alum by vitriolic acid, and the ſiliceous earth is not ſo much as diſſolved by that menſtruum (§ II and III. A).

Others, becauſe common flints are generally found in chalky hills, imagine, that they originate from chalk, particularly depending upon miſunderſtood phænomena of gelatinous minerals: theſe phænomena are explained at large in the treatiſe on Volcanic Products. In the collection of the Academy, there is found an echinites exactly filled with ſiliceous earth, and ſurrounded with the ſame kind of ſubſtance; but the ſhell itſelf is ſtill calcareous, and even of a ſpathaceous form. Now, in this caſe, ſince by hypotheſis the calcareous earth has acquired a ſiliceous nature both internally and externally, how could the ſhell itſelf avoid the change? But the nature of the ſubject, which is ſtill ſo much involved in darkneſs, from the want of a ſufficient number of experiments, that we cannot certainly determine the origin of ſiliceous earth, forbids us to dwell longer upon this point.

§ VII. *In what Form Siliceous Earth occurs in the mineral Kingdom.*

The ſiliceous earth, ſuch as it appears when precipitated from liquor of flints, and freed from all heterogeneous matter, is ſcarcely ever found, at leaſt in the external ſtrata of this globe; but is, like the other primitive earths, more or leſs mixed with other ſubſtances,

ſtances, and that as well mechanically (as is the caſe in common clay) as by a more intimate connection, and, as it were, ſolution; inſtances of which occur in ſerpentinum, aſbeſtos, mica, ſchoerl, garnet, zeolith, and thoſe ſtones which are called ſiliceous. So long as the ſiliceous nature prevails in the maſs, they are not improperly ſo called, the denomination being taken from the prevalent ingredient: but here we muſt obſerve, that the nature of the compound does not always correſpond with the quantity of the different ingredients; for the properties of certain ſimple earths are far more remarkable and intenſe than thoſe of others. Thus a maſs, in which pure clay makes no more than a fourth, nay even ſometimes leſs, yet preſerves the nature and character of clay; therefore it is that we call ſuch mixtures ſiliceous which ſtand the criteria mentioned in § 11; and, although the ſiliceous nature is ſometimes more obſcure, on account of the quantity and quality of heterogeneous matter, it is of no importance, provided the ſiliceous nature and properties prevail.

To this claſs we may, without reſerve, refer quartz and mountain cryſtal, flints, properly ſo called, and jaſpers; but more ambiguouſly petroſilices and felt-ſpar, as alſo zeoliths, ſchoerls, and laſtly garnets, which are as it were intermediate between thoſe and the gems; which are to be entirely excluded from ſiliceous earths, as not only by their nature, but by the proportion of their primary principles, they challenge a place among the clays, as we ſhall ſee hereafter. Moſt of the laſt-mentioned ſtones abound in ſiliceous earths, and contain beſides portions of calcareous and argillaceous earth, yet exhibit the ſiliceous properties notwithſtanding;—the limits and deſign of the preſent Work prevents us from mentioning the ſpecific differences.

DISSERTATION XIV.

OF THE

HYDROPHANOUS STONE.

§ 1. *Peculiar Property of the Hydrophanous Stone.*

BENEDICTUS CERUTUS relates, that he had ſeen with the greateſt aſtoniſhment, in the poſſeſſion of Chr. Furleger, an opake ſtone, which, upon lying in water, by degrees acquired tranſparency, and which, upon drying in the light, became again opake; for this reaſon he denominates it *lapis mutabilis*. Such ſtones were afterwards very ſcarce, and had the empty name of *oculus mundi* beſtowed upon them. The reaſon of the former appellation is obvious; the latter is merely the ſport of a warm

warm imagination. Dr. Hill has very properly called ſuch ſtones as grow tranſparent in water *hydrophanous.*

An attentive conſideration of the change produced will eaſily inſtruct us in the nature of this wonderful phænomenon. The tranſparency may be obſerved proceeding from the ſurface to the nucleus; and at the ſame time air bubbles continually ariſe from the ſurface of the ſtone, and float upon that of the water. Some aſſert, that the tranſparency begins at the center, and extends itſelf to the ſurface; but when that is the caſe it muſt be occaſioned by ſome crack which admits the water at once to the center; all the hydrophani which I am in poſſeſſion of, or have ever ſeen, have, conformably to natural expectation, grown firſt tranſparent at the ſurface.

The phænomena of clouds ſerve to ſhew that moiſt particles, copiouſly mixed with particles of air, prevent the tranſmiſſion of light, and render the maſs more or leſs opake, although the particles of each, ſeparately taken, are pellucid. The cauſe of this is to be ſought for in the difference of refracting power; for by means of that the rays are turned from their original courſe at every particle, a circumſtance which is very injurious to tranſparency. A common experiment will ſtill more clearly elucidate this point:—the moſt tranſparent glaſs, when reduced to powder, becomes opake,

becauſe

because the air, which now occupies the interftices, refracts the light much more weakly than the particles of glafs do; but, upon pouring on water, which difplaces the air, and differs lefs from the glafs in its refracting power, a certain degree of tranfparency is reftored. Setting down the fpecific gravity of water 1,000, we fhall find that of air to be 0,001; and that of glafs varying, according to its compofition, from 1,791 to 3,380, which is the greateft: hence it appears, that the greateft difference between glafs and water is 2,380, and the leaft is 0,791; the greateft difference between glafs and air is 3,379, and the leaft is 1,790. From this calculation we may judge of the different quantities of refraction, and the confequent differences of tranfparency.

Let us now fuppofe a ftone which agrees nearly with water in fpecific gravity, or at leaft is not more diftant from it than glafs; let us alfo fuppofe that its particles are tranfparent, but that it is uniformly perforated by invifible foramina, fo that both air and water may be admitted, though not readily; we fhall then have a ftone, which, when well dried, remains opake, but, like the oculus mundi, grows pellucid in water. The fuperior effect which an alkaline lixivium produces in this cafe, depends on the fuperiority of its fpecific gravity.

Although

Although the caufes of this phænomenon are thus phyfically explained, which always renders a phænomenon much lefs furprizing, yet to this effect three conditions, but rarely found united, are neceffary; fo that ftones of this kind were very fcarce, and valued at great and even immenfe prices. The extravagance of the price alfo prevented the examination of this fubftance; and our ignorance of its nature concealed from us the place where it was to be found; nay, fo undecided were opinions concerning it, that the moft acute examiners were doubtful whether it owed its origin to the mineral or to the animal kingdom: in the mean time the curious, both merchants and philofophers, were bufily employed in fearch of it. The accounts tranfmitted to the Royal Academy of Sciences, Stockholm, were as follow:—

In 1770 the celebrated Quift, who had vifited England, communicated fome obfervations upon three fpecimens which he had feen in the Britifh Mufeum; but as he was only permitted to examine them fuperficially, he could not determine their nature.

At the beginning of the year 1774 Mr. Poetzfch of Leipfic related to the Academy, that the year before a lapis mutabilis had been offered at the electoral collection for the price of 100 ducats; that this ftone very much refembled a certain variety of the Eibenftock opal, which, upon trial, was alfo alſo found to grow tranſparent in water: hence he concludes, that the lapis mutabilis is to be ranked in the family of the opals.

In 1776 Mr. Murray communicated to the academy a diſcovery which had been made three years before by Mr. Veltheim, ſuperintendant of the mines in the Hartz, namely that the grey, green, and yellow hydrophanæ, are no other than thin cruſts of the chalcedony of Ferro.

In 1777 Mr. M. T. Brunnich, profeſſor at Copenhagan, in a memoir gave a confirmation of the chalcedony of Ferro's being the matrix of the hydrophanous ſtone: it is ſufficient juſt to mention this; the other circumſtances may be ſeen in the Act. Stockholm, an. 1777.

Having now mentioned this quality ſo highly prized, and ſhewn its exiſtence in certain of the chalcedony and opal tribe, let us conſider theſe ſtones a little more accurately; although it cannot be denied, that the ſame property may, and actually does, exiſt in ſome other ſpecies.

§ II. *The Opal and Chalcedony compared together.*

The opal and chalcedony agree with one another in many properties.

(A) The common colour of both is frequently milky; but the former is more pellucid

lucid than the latter; befides, the opal, viewed with refracted and reflected rays, exhibits different colours; but this property is not peculiar to it alone.

(B) The chalcedony is of greater fpecific gravity than the opal; but in this refpect they do not differ much: the Eibenftock opal is from 1,958 to 2,075, and the chalcedony of different countries from 2,559 to 4,360.

(C) The opal does not poffefs fufficient hardnefs to ftrike fire with fteel; the fame is fometimes true of the chalcedony: fo that, differing only in degree, they may, with refpect to this property, be confounded.

(D) With regard to compofition, they alfo agree, as I difcovered by the following experiment:—I took 100 parts of chalcedony of Ferro, reduced to a very fine powder by elutriation, and formed it into a little ball, with three times as much mineral alkali, and a fmall quantity of water; after mixing them well together, I dried it, and expofed it cautioufly to the fire in an iron veffel for an hour and a half; this operation requires the fire to be gradually raifed, but not beyond a certain degree. This management is fo difficult, that for once it fucceeds the mafs melts five times; for the more alkali is ufed, the more is the texture of the matter opened, that menftrua may extract the ſoluble parts, but at the ſame time the more is its tendency to fuſion increaſed; but the maſs, when fuſed, muſt neceſſarily be loaded with iron, which renders an accurate ſeparation of the principles very troubleſome; and beſides a portion adheres to the veſſel, which is not eaſily got off: theſe inconveniences, therefore, muſt be carefully avoided; and whoever diſlikes this ſcrupulous attention to the management of the fire, muſt diminiſh the quantity of ſalt, and reduce it to a fourth or ſixth part of the chalcedony; by which means the end may be obtained, but more imperfectly. The ball, upon the application of a proper degree of heat, ſplits into a powder; this powder I collected and kept in marine acid in a digeſting heat, until the reſiduum reſiſted the force of the acid: the inſoluble powder, which was purely ſiliceous, when waſhed and dried, weighed 84 aſſay pounds; ſo that the undiſſolved part conſiſted of 16, which, precipitated and examined, appeared to be all argillaceous, mixed with ſome iron, but without the ſmalleſt appearance of any thing calcareous.

It is proper to obſerve, that the ſame chalcedony, without the previous preparation with alkali, yielded to the marine acid a portion of argillaceous earth, but four times leſs: it differs, therefore, from the common flint, which, treated in this way, yields

yields ſcarce any clay, and is found mixed with calcareous earth, though in leſs proportion than the cryſtals of quartz.

I treated the Eibenſtock opal in the ſame way, and it gave the ſame reſult as the chalcedony, whether crude or prepared with alkali: the argillaceous part was indeed a few pounds leſs; but I do not know that the difference is conſtant.

(F) From the above it appears plainly, I think, that opal is to be conſidered as a rarer and purer chalcedony, and the latter as a denſer and coarſer opal: that the opal is of a more ſpongy texture appears not only from the ſpecific gravity, but alſo from this, that pieces of the opal often grow more tranſparent and more weighty in water.

§ III. *Of the Hydrophanous Flint.*

We have heretofore conſidered the opal and chalcedony; but theſe, when perfect, do not undergo the change in water of which we are treating, at leaſt not in ſuch a degree as to attract attention; but this property is ſometimes found in the cruſts with which they are covered: theſe we ſhall therefore proceed to examine more accurately.

(A) It may in general be ſaid of thoſe ſiliceous ſtones which reſemble the common flint in breaking equally and ſmoothly, that

that they are frequently found ſurrounded with a covering of coarſer materials. I ſhall mention what appears probable concerning the origin of this cruſt :—evident marks frequently occur, which ſhew that theſe ſtones have gradually been indurated, and were originally a tenacious maſs. Now, during this operation, the coarſer particles, or thoſe more imperfectly diſſolved, while the bulk gradually diminiſhed, were puſhed to the ſurface by the more homogeneous matter, or ſometimes towards the center, if any cavity be there to receive them ; but as the maſs grew more denſe, the reſiſtance alſo grew greater, and at length acquired ſo much power as to prevent the protruſion, it therefore obliged the protruded particles to ſettle in ſtrata parallel to the ſurface ; and theſe ſtrata were at leaſt diſtinguiſhable by colour and tranſparency from the reſt of the maſs : inſtances of this are ſeen in agates and chalcedonies. The external layers are generally more coarſe, and have undoubtedly been protruded in the manner above-mentioned, while the maſs was ſoft. On ſeparating the layers, each internal is found of a more delicate texture than the adjacent external.

(B) The above-mentioned cruſts muſt neceſſarily differ in texture, denſity, hardneſs, and gravity ; it is therefore evident, that the three conditions neceſſary to the mutability required, cannot always be preſent in theſe. Experience ſhews that the proper pieces, which are generally ſurrounded with thoſe that are uſeleſs, cannot be diſtinguiſhed by ſight, by touch, or any external mark: thoſe which, when applied to the tongue, do not ſhew any adheſive power, may be rejected; yet thoſe which poſſeſs that power do not always grow tranſparent in water, although they admit it, two other conditions being equally neceſſary. Actual immerſion for 24 hours will decide the queſtion, as thoſe which require longer time are not worthy of attention.

(C) Hitherto we have conſidered the cruſts of ſiliceous ſtones in general; and although the involucra of all the varieties may perhaps ſometimes yield the hydrophanous ſtone, yet experience ſhews that it is chiefly to be ſought for among thoſe of a looſe texture, ſuch as opals and chalcedonies.

(D) The cruſts which grow tranſparent in water, on breaking appear denſe and ſmooth, they ſtick to the tongue, do not ſtrike fire with flint, are of a whitiſh yellow brown, nay ſometimes blackiſh colour: their tranſparency varies according to circumſtances; their ſpecific gravity ſcarcely double that of water.

(E) As theſe ſtones are deſtitute of the hardneſs neceſſary to ſtrike fire with ſteel (a property which is conſidered as the criterion of ſiliceous ſtones) ſome doubt may ariſe concerning the ſiliceous nature of the hydrophanous

hydrophanous crufts: I thought analyfis the moft proper means of folving this difficulty, and upon experiment found the fame principles as before (§ II. E), which puts an end to all ambiguity. But it appears plainly that the greater or leffer degree of connection between the integrant parts affords a very infufficient and fallacious mark of difcrimination; and accordingly we find a great variety in this refpect, even in the fame tribe. We have already fpoken of opals and chalcedonies (§ II. C); the fame is true of cornelians, gems (*a*), &c. We have alfo in clay a very remarkable inftance of the effect of different degrees of exficcation; for this fubftance, although when crude it attracts water ftrongly, and is foftened and penetrated by it, yet by a certain degree of heat it is fo condenfed as to reject water; and at length, by a very intenfe heat, it acquires a perfect flinty hardnefs. In this inftance the very fame matter exhibits very different degrees of cohefion among the particles; and it is elfewhere demonftrated, that, even when hardened to the greateft degree, it yet retains an argillaceous nature; we may therefore juftly conclude, that the degree of hardnefs is not to be confided in.

(F) The value of the hydrophanous ftone is eftimated by its bulk, the quicknefs of the change, and the elegance of its colour.

(*a*) Vid. de Terra Gemmarum.

Of two equally penetrable the larger muſt neceſſarily grow tranſparent more ſlowly; but the effect may be ſomewhat increaſed by diminiſhing the thickneſs or perpendicular attitude, the length and breadth remaining the ſame. By this method many of them may be brought to grow tranſparent in a few ſeconds; and no doubt the wonder is much diminiſhed, if the change does not take place under the eyes of the obſerver: beſides, if ſeveral hours be requiſite, neither can the proceſs be properly examined, nor are the air bubbles expelled by the water ſufficiently viſible.

The colour is derived from iron; now, as that ſubſtance often differs both in quantity and quality, a conſiderable difference muſt ariſe, which generally varies between a yellow and a brown.

(G) That the opal gives admittance to water we have already obſerved; but the change is not very remarkable, becauſe it is of itſelf ſemitranſparent, but if naturally, by ſpontaneous calcination, or artificially, by a gentle heat, it contracts an opacity, we immediately get the hydrophanous ſtone. To make the opal opaque when dry, by means of fire, requires much caution; for if too much heat be applied, eſpecially ſuddenly, it flies into ſmall pieces.

(H) The change is accelerated by uſing the water hot, as it penetrates the foramina more readily, and the foramina themſelves

are

are more open, on account of the heat; but whether it be hot or cold, the very pureſt water ſhould always be uſed, otherwiſe the ſtone will gradually be obſcured; for any water, though clear as cryſtal, leaves, upon evaporation to dryneſs, an earthy reſiduum. When the water then which has been admitted is gradually diſſipated by evaporation, ſomewhat always remains behind; this, on account of its tenuity, for a long time does not injure the tranſparency, but if the operation be frequently repeated it may at length become viſible; but this may be eaſily removed by acids, if, as is uſually the caſe, it is of a calcareous nature. I am not ignorant that in this operation the colouring particles of tinged liquors are excluded, though the vehicles penetrate the ſtone; but it is equally true that alkaline lixivia penetrate, and of conſequence calcareous and other ſolutions will alſo penetrate.

By concentrated vitriolic acid alſo the ſtone acquires tranſparency, but ſometimes the colour is darkened by the acid remaining in the pores, and growing blackiſh; but this may be removed by an alkali. But the nitrous acid, highly dephlegmated, rather dephlogiſticates than diſſolves the iron of the ſtone, and occaſionally produces various hues of yellow; but as acid menſtrua are able to take up a little of the argillaceous earth as well as the iron (§ II. E) there is no doubt but, if frequently uſed, they will gradually change the texture of the ſtone. The water enters at the firſt trial more ſlowly than afterwards; it may therefore happen that a ſtone which at firſt ſcarcely admits water may, by lying a proper time in acids, have its foramina opened and dilated ſo as to admit it freely.

That the ſtone when tranſparent is more ponderous than when opaque, experience ſhews, and the fluid imbibed will eaſily explain the cauſe.

(1) We muſt not omit mentioning, that when the hydrophanous ſtone rendered tranſparent is expoſed to the rays of the ſun, or to an intenſe light, it frequently ſhews a ſpark or ſpot ſhining with peculiar luſtre, which changes to different parts of the ſurface, according to the ſituation of the light. This property, which belongs to opals peculiarly, but not excluſively, is not difficult of explanation, as the hydrophanous ſtone is of the nature of opals; but is thus far imperfect, that when dry it is opaque, when wet however it grows tranſparent, and then acquires completely the properties of the opal. The property is of this nature:—let L M N O, tab. 2, repreſent the ſection of an opal, of a lenticular or ellipſoid form; let the parallel rays of light l m l m, &c. fall upon it, and a light will appear in the oppoſite quadrant above M; in proportion as the incident rays are more oblique, the ſhining ſpot is more narrow and more brilliant;

liant; but the higher the luminous body riſes, the larger and weaker is the ſhining ſpot. Let a light fall, by means of candles, on both right and left quadrant, and two oppoſite ſhining ſpots will appear, but weaker than the ſingle. In open air, in the day-light, the half L M N appears almoſt entirely overſpread with a refracted light, but indefinite, not exhibiting any figure; yet when light is admitted into a chamber through a hole in the window-ſhutter, the ſhining ſpot repreſents the figure of the hole: it alſo repreſents the figure of the flame, and that in an erect ſituation, if l repreſents a lighted candle or the ſun itſelf; therefore the adjacent rays, coming from the ſame points, are refracted within the ſtone, and form the figures of theſe points. When the incident rays are nearly parallel to the plane N Q, two or more curves of that kind called *cauſtic by refraction* diverge from M to the internal parts: thoſe which ariſe from refraction from the oppoſite convex part O L are ſeen within the ſtone, but thoſe which are generated by refraction in the concave part L M N are extended beyond the ſtone, in the plane N Q. In order to obſerve theſe phænomena diſtinctly, let the lighted candle l be placed at a foot diſtance from the perpendicular R P, paſſing through the eye at R, placed about half a foot higher than the flame; then let an ellipſoid opal be held upon the finger, or a card, at the diſtance of an inch from the flame, and the cauſtic curves will appear: if the ſtone ſinks ever ſo little in the line N S, parallel to R P, a refulgent point will appear within the maſs at M, of the colour of the ray which paſſes through it: but at O, or the ſurface, a white ſpot appears; when it deſcends a little lower, in the ſame right line, the points change into flaming figures; at O a white and leſſer one ariſing from reflexion; at M one coloured, and larger, which ariſes from refraction; theſe two, upon the further ſinking of the ſtone, riſe and meet together at L: by uſe we may eaſily learn to produce any of theſe varieties, unleſs the figure of the ſtone be improper, as upon this depends both the number and the differences of the curves. The colour of the figures which ariſe from refraction muſt neceſſarily be the ſame with that which the ſtone tranſmits; for it is known that opals ſeen with reflected and refracted light exhibit different colours: the mountain cryſtals, and other colourleſs pellucid ſtones, however ſuitable their form, do not exhibit theſe phænomena diſtinctly: certain vague collections of light may be ſeen, but a peculiar colour is neceſſary to diſtinguiſh the form of ſuch appearances: this colour is here wanting, as all ſpecies of rays are tranſmitted.

The nature of our ſubject forbids the introduction of any thing more geometrical,

as

as what has been ſaid is ſufficient to explain the true nature and origin of theſe luminous points. We ſhall only add, that the ſtars which appear on the ſurfaces of ſphærical pellucid ſtones by a particular ſituation with reſpect to the light, are generally nothing more than a number of theſe cauſtic curves proceeding from the ſame point—to this perhaps may be referred the aſteriæ of the ancients.

(K) The cruſt of that ſtone which Born calls the *ſpathum piceum*, according to his obſervations, ſometimes grows tranſparent in water, and is akin to the opals in its looſe texture, its not ſtriking fire with ſteel, in breaking ſmooth, and other external marks. Upon analyſis I found it for the moſt part a pure ſiliceous earth, with a little clay; and an exceeding ſmall portion of lime.

§ IV. *Of the Hydrophanous Steatite.*

Although this mutability is chiefly found in the ſiliceous ſtones of a looſer texture, it muſt not be conſidered as peculiar to them alone. The conditions neceſſary for this purpoſe may alſo be found in the other tribes, as we ſhall here prove by an example.

The ſteatites vary much, both in colour and ſubtlety of parts, as is well known. In this

this ſpecies alſo there ſometimes occurs a ſtructure of ſuch a kind as to admit water; and as more than half the weight conſiſts of ſiliceous particles, frequently pellucid, it may be eaſily underſtood how this may be rendered more tranſparent: but the hydrophanous ſteatites, being loaded with magneſia, ſeldom attains the ſame degree of tranſparency as thoſe which conſiſt entirely of ſiliceous earth, which are alſo more hard, tho' they yield in beauty and variety of colour to the others. Dr. Brückman mentions red, white, grey, and green ſteatites, poſſeſſed of this property; theſe he directs to be prepared firſt by boiling in an alkaline lixivium, and then in vinegar.

Experiments, if ſufficiently multiplied, will doubtleſs diſcover hydrophanous ſtones in other ſpecies.

DISSER-

DISSERTATION XV.

OF THE

EARTH OF GEMS.

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§ 1. *Various Opinions concerning the Earth of Gems.*

FROM the moſt remote ages, the tranſparency, the ſplendor, the colour, and hardneſs of gems have attracted the attention of mankind, ſo that, not only in the time of Theophraſtus the Ereſian, they were dignified by the name of precious ſtones; but in our days this product of the mineral kingdom is very dear, and not to be had but at an enormous price: but although it is very reaſonable to admire, with Pliny, the perfection of their nature; yet, to the bulk of mankind, more ſolicitous about external glitter than internal perfection, they have rather

rather ſuggeſted the idea of making them ſubſervient to vanity and luxury, than that of examining their real perfections. Their ſcarcity and extreme dearneſs for a very long time prevented them from being accurately examined, from whence it often happened that the wealthy paid dear for their ignorance, purchaſing the ſpurious or artificial gems as genuine.

In the mean time mineralogiſts included them in their ſyſtems; but as they truſted too much partly to external appearances, partly to other fallacious marks, it was impoſſible but they muſt diſagree about the arrangement; and certainly, ſo long as their analyſis was not underſtood, no man could (unleſs accidentally) aſſign their true places, as long as it was unknown whether their earthy baſe was ſimple and primitive, or compound and derivative. Such as rank the gems among ſaline bodies, regard chiefly their figure; but theſe men do not conſider that determinate forms by no means depend upon ſaline nature (although ſubſtances which are ſoluble in water are in a particular manner diſpoſed to cryſtallization) inaſmuch as metallic, inflammable, and earthy bodies, afford cryſtals, and thoſe not unfrequently of a very beautiful kind; and in general the property of cryſtallizing ſeems to belong to every ſolid body, provided its particles be ſo ſubtilely divided and ſuſpended (either in the dry or the humid

mid way) that while they are again concreting they may be at liberty to obey their mutual attraction, and aſſume a ſymmetrical ſituation : in ſalts themſelves the ſpecies of figure depends not upon the acid, nor yet upon the baſe which is united to it. The vegetable, as well as the mineral alkali, with marine acid aſſumes a cubic figure; but the ſame acid, with volatile alkali, terra ponderoſa, mercury, biſmuth, cobalt, and other ſubſtances, aſſumes forms of a very different kind. If therefore in this caſe the acid has no effect, how will it act when it cannot be diſtinguiſhed by any experiment, but its preſence is inferred by bare conjecture?—The ſame may be ſaid of the baſe; for each alkali, with different acids, yields diſſimilar cryſtals. Alum and ſalited cobalt, when properly cryſtallized, yield octaedra, a figure which neither correſponds with the menſtruum nor the baſe; and what are we to think of the pyrites, which occaſionally exhibit every one of the regular geometrical figures?—but we have no need of multiplying examples, if that be known, which I think has been already ſufficiently demonſtrated, namely, that from a few primitive forms of the ſame ſubſtance, a great many derivatives, and thoſe very diſſimilar, may ariſe. Theſe things being conſidered, I do not ſee with what propriety the diamond and the ruby are aſſociated with alum, of which they do not ſhew the ſlighteſt veſtige: but if,

after

after all, we are rather to truſt to occult principles, on this foundation we may make alum of ſalited cobalt, and the other octaedral ſalts. On this hypotheſis too the cubic diamond would be enumerated along with ſea ſalt; and that which is an hexagonal priſm, terminated at each end by three rhombi, among the ſchoerls.

Thoſe who rank the gems among vitreſcible ſtones, beſides various negative criteria of leſſer moment, maintain that they have a gloſſy appearance, and that, in fuſion with fixed alkali, they run into a pellucid glaſs; the former of theſe circumſtances is very fallacious, the latter indeed refers to a quality more eſſential. But we ſhall ſee hereafter what experiments ſhew on this head: hardneſs is in general but a very vague mark, as it often depends entirely upon the degree of exſiccation, the ſubſtance ſtill remaining the ſame, as appears ſufficiently in ſoft clay, when well burned. What ſome call vitreſcent earths, others denominate ſiliceous; but names change not the nature of things, thoſe being the beſt which are adapted to it.

In drawing up a ſyſtem of mineralogy, if the figure, texture, hardneſs, colour, tranſparency, magnitude, and other external appearances, were every where and always ſufficient to diſtinguiſh mineral bodies, this would perhaps (to beginners) be the moſt eaſy method, but it ſtill would not be the

 beſt,

beſt, as theſe properties of bodies, which are applicable to human purpoſes, are derived from the nature of the conſtituent parts, and but rarely from the external appearance. No one is ignorant how fallacious ſuperficial characters are, at leaſt no one who has the leaſt idea of modern mineralogy.—But ſuch is the condition of man, that when he is led by the hope of ſucceſs to attempt impoſſibilities, a long time paſſes before he returns to wiſdom.

Among the moſt modern ſyſtems of mineralogy the moſt perfect by far is that of the illuſtrious Cronſtedt, a ſyſtem which he propoſed with ſo much modeſty as to conceal his name. In this all the ſubſtances are arranged according to their principles: if he ſometimes conſiders thoſe as ſimple which in reality are compound, it is not to be laid to his charge, as theſe errors proceeded not from a defect in his plan, but from the want of a ſufficient number of experiments:—if he has not every where found out the right path, he always ſeeks it with candour, and deſcribes it with preciſion. Treading in his ſteps, I have for many years laboured in the analyſis of the mineral kingdom, in queſt of the foundations for a ſyſtem of natural hiſtory, more expreſſly adapted to the improvement of natural philoſophy, and the advancement of public and private utility.

In various little eſſays I have, in a curſory manner, mentioned the concluſions drawn from

from my experiments: in this place I am eſpecially to treat of gems, in which claſs thoſe cryſtals only are generally ranked which very much exceed the mountain cryſtals in hardneſs.

§ II. *Habitudes of the Gems examined by the Blow-Pipe.*

The tube which goldſmiths uſe for ſoldering, and which is employed by a few other artificers, is well adapted for experiments in mineralogy; its uſefulneſs and convenience recommend it much, as I have at large mentioned in a treatiſe on that inſtrument. This is of the greateſt uſe in the examination of gems, as the ſmalleſt pieces that can be taken up by a forceps (which in this caſe are ſufficiently expenſive) will ſerve for theſe experiments.

It is neceſſary at the very firſt to diſtinguiſh the diamond from the reſt, as it is much harder than them, and alſo differs in other particulars.

Powdered diamond, expoſed to the flame on a piece of charcoal, ſoon grows white, but ſcarcely undergoes a ſenſible change, as it is difficult to keep up the flame conſtantly for ſo long a time as is neceſſary to reſolve it into vapour; while at the ſame time, for ſo long a continuance it is ſcarce poſſible to avoid ſome ſmall inequality in the blowing, which will ſcatter it about; in this reſpect other gems entirely agree with the diamond.

In order to obtain ſolutions of minerals by the *via ſicca*, I employ chiefly three different kind of ſalts, namely, an acid, an alkaline, and a neutral. I am not acquainted with any acid which can endure the fire upon charcoal, except that of the microcoſmic ſalt: this ſalt is neutral, but triple, containing both the volatile and mineral alkali. The phoſphoric acid, ſaturated with volatile alkali, cannot be brought to cryſtallize; which yet always happens, upon the acceſſion of a proper quantity of mineral alkali, and the triple ſalt which reſults from hence is commonly called microcoſmic ſalt. Upon fuſion on the charcoal, this ſends forth its volatile alkali, ſo that the portion of acid which had been before ſaturated with it, being now ſet at liberty, is the better able to exert its effects upon other bodies. I make choice of the mineral alkali well depurated; the vegetable, on account of its deliqueſcence, is leſs proper. Of late I make uſe of borax, as being a ſalt nearly neutral, both the principles of which are fixed in the fire, and are much diſpoſed to vitrification.

I have tried the effects of theſe ſalts upon the gems:—the microcoſmic ſalt attacks them with difficulty, yet diſſolves them; and with reſpect to this ſalt, there is a remarkable difference between the diamond and

and all the other gems; for a ſmall piece or a very ſubtile powder of it, immerſed in a globule of this ſalt in fuſion, during the fuſion immediately floats upon the ſurface, at firſt ſending forth ſlowly a few bubbles, which, upon continuing the operation, entirely ceaſe. If the apex of the flame be kept conſtantly on the powder, it is gradually diminiſhed, but is partly conſumed by the fire, partly diſſipated by the blaſt, and the reſiduum, which is very ſmall, perhaps diſſolved. The particles of the other gems enter into, and remain in the fuſed ſalt without efferveſcence; they wheel circularly about with great velocity, and are by degrees taken up, yielding water-coloured globules, unleſs when they are coloured, which, on vitrifying, they ſometimes are, eſpecially when hot.—Theſe gems therefore are fixed to the ſalts by a more powerful attraction than the diamond, which on the contrary ſhews a ſort of repulſion.

The mineral alkali, fuſed in a ſilver ſpoon [charcoal abſorbs it] takes up the ſmalleſt particles of gems, and notwithſtanding a long continued flame ſcarcely diminiſhes them; yet the emerald is reſolved into a powder, but a refractory one. The diamond ſeems to elude its force altogether, as will appear from what follows.

Borax diſſolves them almoſt in the ſame manner as microcoſmic ſalt, but ſomewhat more quickly, and without any efferveſcence; but the diamond is more weakly attacked, ſo that after a long-continued fuſion the globule adheres to the charcoal, and the powder lying on the ſurface is in the mean time diſſipated.

The powdered diamond, before it is examined, muſt be depurated by aqua regia, for all that which is for ſale abounds with heterogeneous matters, as we ſhall ſee hereafter (§ III. B). As the diamond exceeds all the reſt in hardneſs, as it is by fire diſſipated into ſmoke, and in all its habits differs from the reſt, which in general agree with one another: theſe ſhall in the future be ſpecifically comprehended under the name of gems.

The habits above deſcribed, eſpecially thoſe with the mineral alkali, diſtinguiſh the gems very completely from the mountain cryſtals, which are not only taken up by alkali, but alſo with a vehement ebullition or effervefcence: thoſe artificially made, which conſiſt of an hyaline, or coloured glaſs, immediately betray themſelves, by fuſing without any addition.

Hence it appears that the diamond and the gems form genera as much diſtinct as quartz, garnet, ſchoerl, and many ſtones; yet it remains to be examined, whether the earthy baſe of each be primitive or derivative; and if the latter be the caſe, what ſimple elements, and in what proportion, conſtitute it?—Theſe queſtions cannot be anſwered but by the *via humida*, to which we ſhall therefore have recourſe.

§ III. *Cautions to be obſerved, and Difficulties occurring in the Analyſis of Gems.*

In this examination many obſtacles occur, the chief of which we ſhall conſider ſeparately.

(A) The dearneſs of the matter not only perſuades but obliges us to uſe ſmall quantities; and in the operation we muſt be very cautious to avoid the loſs or addition of any thing, as in an experiment on ſo ſmall a quantity the leaſt difference is of great conſequence, though in a larger quantity it might be almoſt entirely neglected.

(B) Pulverizing the gems is attended with many inconveniences; they are poſſeſſed of ſuch a degree of hardneſs that they are in this reſpect ſuperior to all other bodies; when immerſed, red hot, in cold water, they become ſcarcely more friable, though by this method the moſt ſolid mountain cryſtals are very eaſily comminuted. Struck by the hammer on an anvil the grains of mountain cryſtal ſplit in general, but the fragments often fly about; and as to the diamond it frequently penetrates both the anvil and the hammer.—The diamond-powder which is for ſale contains heterogeneous matters: from that which I got from the Baron Alſtromer, and which had been lately

lately brought from Antwerp, aqua regia extracted 0,12, without the affiſtance of heat: the menſtruum thus loaded was yellow: fixed alkali threw down a whitiſh powder, which, expoſed alone to the blow-pipe, melted into an opake globule of a metallic appearance; this efferveſced with lime, with borax, and microcoſmic ſalt; but the globule, with microcoſmic ſalt, when loaded with a certain quantity, grew red on cooling, paſſing in a ſingle inſtant from the moſt ſplendid reddiſh tranſparency to opacity. There is no doubt but that this foreign mixture is owing to the inſtruments made uſe of, for which reaſon the powdered diamond is ſold at a ſmaller price than pieces of diamond ſo ſmall that they are of no uſe but for pulverization.

The other gems are much more eaſily comminuted, and at length may be united with water; while the pure water is milky, it is to be carefully decanted, and freſh poured on repeatedly, until by degrees the whole maſs has acquired ſuch a degree of ſubtilty, that it can remain ſuſpended, though remaining at reſt for ſome minutes. The moſt extenſive ſurface poſſible is neceſſary, that the menſtrua may be able to looſen the cloſe connection of the primitive principles; but as the agate is much inferior in hardneſs to the gems, ſomething of the ſiliceous earth muſt neceſſarily be abraded, even by the moſt gentle triture, which is mixed, and, although known as to its nature, nearly unknown as to quantity, unless by weighing the veſſel exactly before and after, eſpecially if it be convenient to make experiments upon ſmall quantities only.

(c) It is not a little difficult to procure ſuch veſſels as are fit for theſe experiments in the dry way. The common crucibles have rough ſurfaces filled with little holes, which hide a quantity of the matter very conſiderable where experiments are made upon minute portions; and what is ſtill worſe, they conſiſt of argillaceous and ſiliceous earth mixed, which muſt render our concluſion fallacious and uncertain, eſpecially when fixed alkali is uſed. In order to diſcover the effect produced by this circumſtance, I made the following experiment:—a ſmall Heſſian crucible, exactly balanced, weighed 1,585 aſſay pounds; into this I put 100 of dry ſalt of tartar, and expoſed it for 37 minutes to a melting heat; but upon cooling I found no more than 1,645; ſo that 40 pounds had flown off, owing, no doubt, to the aerial acid and the moiſture; the former adhering to the alkali, the latter both to the ſalt and the crucible. The fuſed pellucid maſs at the bottom at firſt reſembled a glaſs, but was by degrees obſcured by attracting the watery vapours from the atmoſphere: this I firſt waſhed with warm water, which, when decanted off, formed a jelly; when well waſhed,

waſhed, firſt with vitriolic acid, then with warm water, and dried, it weighed 12 lb. which, upon examination, appeared to be altogether ſiliceous. The ſolution precipitated by fixed alkali, gave 6 lb. of earth of alum; beſides, the crucible was remarkably corroded, particularly about the ſurface of the fuſed maſs. Hence the particles and fragments which were ſeparated in the waſhing, when dried weighed 10 lb. but the crucible itſelf, well waſhed and dried, now weighed 1,594 lb. which is greater than its weight when new; therefore, as $12 + 6 + 10 = 28$, and $1,585 - 28 = 1,557$, and $1,594 - 1,557 = 37$, it is manifeſt, that during the fuſion the fixed alkali had extracted 12 lb. of ſiliceous earth, that is nearly $\frac{1}{8}$ its own weight, and 6 of clay, or nearly $\frac{1}{16}$; and that beſides the crucible retained 37 lb. of fixed alkali, which covered the bottom with a vitreous cruſt not at all ſoluble in water: theſe circumſtances ſhew plainly, that we muſt not truſt to the crucible in decompoſing the ſeveral genera of earths by the dry way, as it will ſuperadd heterogeneous matters, or at leaſt change the proportions of the principles.

In the examination of quartz, I have for many years made uſe of the iron diſhes which are deſcribed in the Treatiſe de Terris Geoponicis. It is well known, that the common rods of this metal are of a parallelopiped

lelopiped form, two of whoſe oppoſite ſides are broader than the other two; I made choice of forged iron of the beſt kind; the rod I had cut into pieces of an inch in length, and on each of the broader ſurfaces I hollowed out a ſegment of a ſphere; in theſe cavities, when cleaned and poliſhed, I put the mixtures with alkali, and by an iron cover prevented the falling in of aſhes and coals. I alſo made trial of another metal, namely, platina precipitated from aqua regis by ſal ammoniac, and afterwards fuſed by microcoſmic ſalt, and then formed, by hammering, into a little cup; but the large pieces of regulus obtained this way were brittle, and none but thoſe which were very ſmall were ſo perfectly fuſed as to be malleable. The little cups made of this metal could therefore only contain a few grains; but if they can ever be obtained of a proper ſize, they will be in all reſpects the beſt, as being infuſible by fire; and if at firſt they be ſufficiently boiled in marine acid, the maſſes afterwards fuſed in them will not be adulterated with any iron; they may indeed be elixated by any acid menſtruum, except aqua regis.

If the mineral earths are fuſed in iron diſhes, by means of alkaline ſalts, a conſiderable quantity of the iron is mixed with them, which renders the ſeparation of their primary principles extremely difficult; but by a proper regulation of the degree of fire the

the desired end may be obtained without any inconvenience, as we shall hereafter see.

(D) In these experiments it is necessary to have the menstrua much purer than they are generally found. The vitriolic acid which is for sale is adulterated with a variety of heterogeneous matters, and among others sometimes with gypsum and vitriol, which occasions a considerable difference in enquiries such as ours. No other, therefore, is to be employed but such as has passed over from a low cucurbit by a gentle distillation.

The other acids too require to be depurated by a peculiar distillation, for it is particularly necessary that they be freed from all earthy or metallic mixture, as such must confound the quantity and quality of the principles which are explored by the analysis.

The common alkali of tartar is always adulterated with siliceous atoms, the weight of which frequently amounts to 0,02; these in the strong acids immediately are separated, but being united with the alkali, remain in the watery solution until the menstruum has attracted aerial acid from the atmosphere, which proceeds very slowly; for this reason, in experiments which require much accuracy, I use no other alkali than the mineral well depurated, or the vegetable extracted by distilled water from cream of tartar

tartar in a well-burned glaſs veſſel, which manifeſts no ſigns of ſiliceous earth.

§ IV. *Power of Acids in decompoſing the Gems.*

There are only yet diſcovered five ſpecies of earths, which are ſo ſimple that they cannot, by any means hitherto known, be reſolved into more ſimple ones, nor be tranſmuted one into the other; theſe are therefore called primitive earths, and that with juſtice, until new experiments evince the contrary:—theſe are terra ponderoſa, lime, magneſia, argillaceous and ſiliceous earth. It cannot be denied that it is not altogether without probability ſome imagine that the number of theſe earths ſhould be diminiſhed, conſidering them all as modifications of one; but in the explanation of nature, we muſt not ſo far indulge conjecture, as to ſuffer the vain phantaſms of imagination to prevail over phænomena confirmed by conſtant experience, and not impeached by a ſingle experiment, when made with accuracy. Four of the above-mentioned earths are ſoluble in certain acids; the fifth alone rejects all acids, except that of the mineral fluor. If, therefore, ſome of theſe, in greater or leſs number, be united into one maſs, chemiſtry is able to ſeparate them all by the uſe of appropriated menſtrua: enlarging the ſurface of contact aſſiſts the

the action of the menſtruum very much, the earth muſt therefore be reduced to a very ſubtile powder. Sometimes, however, mechanical diviſion is not ſufficient, and the operation muſt be performed chymically, which, in the preſent inſtance, is done in the dry way, by means of an alkaline ſalt, which by attacking the ſiliceous earth looſens the connection of the principles—to what degree the uſe of mechanical pulverization alone may be carried, we ſhall ſoon ſee.

(A) Vitriolic acid did not attack the diamond in any way in which I have hitherto employed it; but I muſt confeſs, that I made uſe only of very ſmall portions: I choſe the ſmalleſt fragments of the thinneſt lamellæ, being very reaſonably diſtruſtful of the powder which is for ſale. A double weight of vitriolic acid, highly concentrated, added to a very ſubtile powder of the other gems, and afterwards diſcharged by boiling to dryneſs, operates very powerfully; for the reſiduum, elixated with warm water, yields not only a metallic colouring ſubſtance, but a ſmall portion of lime: the metallic part, precipitated by a phlogiſticated alkaline lixivium, yields a beautiful Pruſſian blue; ſo that from hence it clearly appears, that the red colour of the ruby, as well as the blue of the ſapphire, the yellow of the topaz, the tawny of the hyacinth, and the green of the emerald, is to be attributed to iron;

iron; the quantity of which I determined by that of the blue precipitate. As I have elſewhere (*b*) demonſtrated, that ſix parts of the Pruſſian blue are obtained from one of the diſſolved iron, I precipitated the calcareous matters with an alkali, and it was found ſo pure, that with vitriolic acid it did not ſhew the ſmalleſt traces of argillaceous earth, except in the decompoſition of the ſapphire. Below are found the quantities extracted from 100 aſſay pounds, expreſſed in hundredth parts, or ſingle pounds.

		Aerated lime.		Iron.
The ruby, red	- oriental	9	—	10
ſapphire, blue	- oriental	7	—	2
topaz, yellow	- Saxon	8	—	6
hyacinth, tawny	- oriental	20	—	13
emerald, green	- oriental	8½	—	4

By this method all the calcareous earth and iron are extracted, as will appear hereafter.

(B) Concentrated nitrous acid, by digeſtion and decoction, yielded nearly the ſame reſult; I uſed eight times the quantity of this menſtruum, continued the digeſtion for two days, and the boiling for an hour; I cautiouſly decanted off the clear liquor, and poured on again the ſame quantity of menſtruum, digeſted, and then boiled it: this

(*b*) De Min. Doc. hum.

operation I repeated twice more, and then ſtopped, as the laſt liquor contained very little diſſolved matter.

Theſe liquors, collected and precipitated, gave nearly the ſame reſult as mentioned in A, at leaſt with regard to the lime; and in the iron the difference never exceeded 0,02. The nitrous acid, eſpecially when aſſiſted by heat, dephlogiſticates the iron, and in that caſe takes it up with great difficulty: hence too, in this experiment, the iron was mixed with a little ochre.

The diamond rejects this menſtruum as well as the former.

(c) I employed the concentrated marine, as well as nitrous acid; and with the ſame ſucceſs, except that it extracted the iron better than even vitriolic acid, but the difference did not exceed 0,01.

We ſee, therefore, that from the gems properly ſo called a ſmall quantity of lime and iron may be extracted by acid menſtrua; but as what is extracted ſcarcely amounts to $\frac{1}{5}$ of the whole, and after the ſeparation the reſiduum is nearly of the ſame nature as before, I began to conjecture that the extracted part is accidental, and that the reſiduum conſtitutes the particular primitive earth; and this is an opinion which I have publiſhed in other works. In the mean time, however, the few veſtiges of argillaceous earth which are extracted from the ſapphire, and which ſometimes amount to

0,02,

0,02, ſtarted a ſcruple of great weight; as I had often before experienced that bodies which, notwithſtanding the moſt ſubtile mechanical pulverization, appear inſoluble, yet upon being diſſolved in another menſtruum are afterwards actually taken up by the very menſtrua which before were ineffectual: I therefore tried in many ways to effect my purpoſe. One part of alkaline ſalt, by means of a due degree of fire, reduces two parts of quartz or flint to a tranſparent ſtrong glaſs; but as the proportion of ſalt is encreaſed, the glaſs becomes the worſe, and is not only corroded by acids, but, if it contains a double quantity of ſalt, deliquiates in the open air: by this method a glaſs may be had ſoluble in water. The gems could not heretofore be reduced to tranſparent maſſes by means of alkali, and a quadruple quantity of ſalt is requiſite to make them coaleſce in fuſion to a certain degree; but as this operation cannot ſafely be performed but in iron veſſels, in which caſe the maſs not only adheres obſtinately to the veſſel, but is at the ſame time loaded with iron, this method is liable to great inconveniencies; but upon trial I have found that fuſion is not neceſſary, and that the purpoſe is equally anſwered, if the quantity of alkali be ſuch that the particles may coaleſce by an incipient fuſion. Hence reſults a method which I have found extremely convenient in the examination of minerals,

rals, the application of which to the gems I am now to deſcribe.

§ v. *Method by which the proximate Principles of Gems are moſt eaſily determined.*

(A) The gems are to be reduced to a moſt ſubtile powder, which may be effected by trituration and elutriation.

(B) A determined weight of this powder (the larger the quantity the better) is to be mixed with double its weight of depurated mineral alkali which has undergone ſpontaneous calcination.

(C) Let the mixture be put into an iron diſh, the inſide of which ſhould be ſmooth and poliſhed, leſt the ſmall pieces, which by calcination eaſily ſeparate from the metal, be mixed with the contents of the veſſel.

(D) Let the diſh be placed in a wind-furnace, upon a tile, and covered by an inverted crucible, to keep off the coals and aſhes.

(E) Let it be kept moderately hot for three or four hours; if the heat be too great the maſs adheres to the bottom of the veſſel: a blaſt is not to be employed, leſt the iron ſhould ſwell, and go off in ſcoriæ.

The firmneſs and coherence of the maſs, and its being eaſily ſeparable from the veſſel, without any mixture, ſhew that the fire has been properly regulated; which may be eaſily learned by a few trials.

(F) Let

(F) Let the maſs, carefully ſeparated from the veſſel, be powdered in an agate mortar; and let all that is ſoluble be extracted from it by marine acid, in a digeſting heat.

That nothing more remains to be extracted, may in ſome meaſure be judged by the light and ſpongy nature of the reſiduum, but more certainly by the addition of a new portion of acid, which, when digeſted for ſeveral hours, does not take up any thing.

(G) The ſolution being finiſhed, the reſiduum is collected and waſhed well, dried, and weighed. The deficiency of the former weight determines the quantity diſſolved.

(H) The ſolution is yellow, which indicates the preſence of iron: this is yet more certainly manifeſted by an alkaline phlogiſticated lixivium, and therefore the ſolution ſhould be firſt precipitated by this, properly ſaturated. The Pruſſian blue is collected, waſhed, and dried; the ſixth part of which indicates the quantity of iron.

(I) The earth, freed from all the metallic parts, is precipitated by a fixed alkali, purified completely from ſiliceous earth: let the precipitate, waſhed, dried, kept red hot for half an hour, and then weighed, be plunged into ſix times its weight of diſtilled vinegar, which in the cold, in the ſpace of an hour will diſſolve all the lime, magneſia, or terra ponderoſa, which is preſent; but

does

does not take up any confiderable portion of clay, unlefs by a long digeftion.

(K) The vinegar filtered, yields to an aerated fixed alkali all the earth which it held diffolved, which muft be edulcorated and weighed. I mention particularly an aerated fixed alkali, as fuch an one precipitates even terra ponderofa, which eludes the cauftic alkali.

(L) The nature of the precipitate thrown down from the vinegar is next to be examined: if this be put into diluted vitriolic acid, the middle falt generated will readily determine the bafe; for with terra ponderofa this acid generates fpathum ponderofum infoluble in warm water, though a thoufand times its quantity. With lime it produces gypfum, which excites fcarcely any fenfation of tafte, and diffolves in five hundred times its weight of warm water, but is immediately thrown down from this folution by acid of fugar in the form of faccharated lime. With magnefia it forms Epfom falt, extremely bitter, foluble in its own weight of warm water, and quickly deftructible by lime-water.

(M) The refiduum collected (G) muft alfo be examined, which is beft done by the blow-pipe: thefe refidua, in fmall portions, muft undoubtedly be very minute, and therefore fhould not be treated in large veffels: befides, the ordinary crucibles are by no means fit, where filiceous earth is con-

 cerned,

cerned, nor are veſſels of iron ſafely to be uſed, as fuſion is neceſſary (§ III. c). Theſe inſoluble reſidua are found to conſiſt either of particles of gems not yet ſufficiently divided, or of ſiliceous earth, as all the other earths yield to the force of the acid.

This operation is eaſily performed by the blow-pipe, in the following manner :—let a piece of mineral alkali be fuſed in a ſilver ſpoon, and to it be added a ſmall quantity of the reſiduum; the circumſtances of their union are then to be carefully obſerved, for if the reſiduum enters the fuſed alkali with a vehement efferveſcence, and is all quickly diſſolved, it is truly ſiliceous; but if it enters without efferveſcence, and afterwards continues rolling about in form of a powder (which, as the fuſed maſs is tranſparent, may eaſily be ſeen) we may conclude that there ſtill remain in it ſome particles of the gem.

(N) The reſiduum mentioned (L) has been alledged to be argillaceous; but to demonſtrate this, let it be treated with thrice its weight of concentrated vitriolic acid, ſo that the liquor may evaporate to dryneſs; the remaining maſs, if the baſe be argillaceous, will diſſolve in twice its weight of warm water, produce a ſweetiſh aſtringent taſte in the mouth, yield octaedral cryſtals, be quickly precipitated by cauſtic volatile alkali, and exhibit the other characters by which alum is diſtinguiſhed.

§ VI. *Proxi-*

§ VI. *Proximate Principles of the Gems.*

I have examined the gems in the manner above defcribed:—the refiduum of G I found purely filiceous; the precipitate of H, a genuine Pruffian blue; that part diffolved by diftilled vinegar in K, wholly calcareous; and what remained undiffolved, argillaceous: fo that I entertain no doubt concerning the quality of the principles. As to the quantity and relative proportions, many experiments are neceffary to determine that point; for I have only ufed very fmall quantities, not exceeding an affay hundred. Upon fubjecting the matter of the fame cryftal twice to experiment, a difference occurred fcarce exceeding $\frac{1}{100}$; but different cryftals, *v. g.* different rubies, differed more, even to 0,07. Doubtlefs in every fpecies the proportions may vary a little, within certain limits, which yet remain to be difcovered.

Here follow the mean quantities extracted from each 100, according to my experiments: as the argillaceous earth forms the largeft part of all of them, I have arranged them according to the quantity of that ingredient.

	Clay.	Siliceous Earth.	Lime.	Iron.
Emerald -	60	24	8	6
Sapphire -	58	35	5	2
Topaz -	46	39	8	6
Hyacinth -	40	25	20	13
Ruby -	40	39	9	10

By clay I mean nothing more than the earth of alum, which is found in all clay mixed with siliceous powder (§ v. n). By siliceous earth I understand such as principally constitutes pure quartz, mountain crystal, and flints (§ vii). The numbers in the third column point out aerated lime: a doubt may indeed be started, whether it enters into the composition pure or aerated; if the latter be the case, the closeness of its connection with the other principles, and the smallness of its quantity, which never exceeds $\frac{1}{6}$, and is in general less than $\frac{1}{10}$, may be sufficient to prevent any diminution of weight in the fire, or any visible effervescence with acids; but the deficiency of weight which nevertheless occurs seems to indicate that it enters the composition aerated. Out of 100 parts one or two are easily dissipated in the various operations in different vessels and filters; which accounts for some of the deficiencies in the above table; but 5, 8, and much less 12 parts, could not escape proper accuracy in that analysis, which last would be the case in the decomposition of the hyacinth, on the supposition that the lime was present free from aerial acid. I could observe nothing volatile, after an exposition of several hours to a white heat, nor upon the addition of acids is any thing sublimed while they pass over into the receiver.

The

The laſt column ſhews the quantity of metallic iron, which, diſſolved in acids, and precipitated by phlogiſticated alkali, yields a quantity of dark Pruſſian blue, equal to that obtained from the ſeveral gems reſpectively (§ v. H). Now the iron is here preſent in a calcined ſtate, and this metal, like others, has its weight increaſed by calcination, ſometimes amounting even to 0,36: hence it follows that the quantity of martial ingredients is ſomewhat greater than is denoted by the numbers; and this metal gives birth to different colours, not only in proportion to its quantity but its quality, that is, the quantity and modification of the phlogiſton remaining in the calx.

From the above it may alſo be collected, that the gems agree in this reſpect; that they all conſiſt of the ſame principles; and that of theſe the argillaceous earth forms the greateſt part, then the ſiliceous, next the calcareous, and leaſt of all the iron;—the two firſt ingredients vary extremely.

The knowledge of the principles muſt neceſſarily throw ſome light on the properties. Theſe gems exceed all other bodies in hardneſs, the diamond excepted; and we find upon analyſis, that they abound in argillaceous earth. Hence we may form ſome judgment of the prodigious degree of exſiccation requiſite to occaſion ſuch a degree of hardneſs. The heat of the temperate zone is found inſufficient for this purpoſe, and the

the more conſtant and intenſe heat of the tropical climate is requiſite: condenſation is the neceſſary conſequence of this hardneſs, hence the gems are more ponderous than the other earthy cryſtals.

The gems, except emerald and hyacinth, reſiſt the moſt intenſe fire; yet we know that the ruby has been ſoftened in the focus of a burning mirror. Experience alſo ſhews, that the four principles of which they are compoſed, according to their various proportions, form mixtures with very different degrees of fuſibility: fixed alkali attracts ſiliceous earth very powerfully, but ſcarcely acts upon argillaceous earth or lime; hence it is with difficulty it acts upon the gems in which not only the ſiliceous earth is in ſmall quantity, but is alſo cloſely united with the other principles; yet in the emerald, which is inferior in hardneſs to the reſt, the looſer texture permits the alkali to attack the ſiliceous earth more readily; hence, when expoſed to the blow-pipe with this ſalt, it is reſolved into a powder, with a momentary efferveſcence. The microcoſmic ſalt diſſolves lime and argillaceous earth very well, but hardly the ſiliceous; yet, as this is but in ſmall quantity, by means of the former the latter is taken up though ſlowly. Finally, borax, which in the dry method, ſtrongly attracts all the principles, diſſolves their combinations more eaſily than the other ſalts.

The

The ſame kind of delay which the argillaceous and calcareous earths occaſion in the action of fixed alkali, by covering the ſiliceous earth, does the cloſe union of that earth with them occaſion to acid menſtrua; ſo that, without ſome previous preparation with alkali, ſcarcely any thing can be extricated, except the lime and the metallic part.

§ VII. *Cryſtals allied to the Gems.*

Upon conſidering what has been ſaid, I believe no one will deny that in a ſyſtem of natural hiſtory the gems belong to the tribe of compound argillaceous ſubſtances; but as nature operates by inſenſible degrees, it will not be improper here to conſider other cryſtals which are nearly related to the gems; for by increaſing the proportion of ſiliceous earth a great number of ſubſtances, compoſed of the ſame materials, will appear, differing from them more or leſs. To this claſs belongs a number of ſtones, ſuch as garnet, ſchoerl, zeolith, and quartz; the two former of theſe, examined in the ſame way as the gems (§ V.), exhibit the ſame principles, but in thoſe the ſiliceous earth predominates over the argillaceous; yet is the connection of the principles ſo cloſe, that the garnet always ſtrikes fire with ſteel, and the ſchoerl not unfrequently. Theſe are followed by the zeolith, the texture of which is ſo lax that acids ſeparate its conſtituent parts, without any other previous preparation than a mechanical pulverization. The zeolith very ſeldom ſtrikes fire with ſteel, yet is ſometimes found hard enough for that purpoſe: ſuch is the white zeolith of mount Moeſſeberg in Weſt Gothland, and the green in the gold mine at Adelfors: it is alſo very ſeldom tranſparent. The quartz forms as it were the extreme link of the chain; for this abounds ſo much with ſiliceous earth, as almoſt to conceal the other principles: if the analyſis be attempted with a double quantity of mineral alkali, it is extremely difficult to moderate the fire ſo as to prevent fuſion; the ſalt muſt therefore be reduced to $\frac{1}{8}$.

If the menſtrua be afterwards employed in the manner deſcribed for the gems, very little clay or lime is obtained. I am not certain whether there be any mountain cryſtals entirely ſiliceous, which perhaps may be the caſe. I have long ſince declared, that I did not diſcover any argillaceous earth; but at the ſame time I obſerved that the experiment was imperfect.

It will be proper to conclude, by eſtabliſhing the characters of the ſtones which have been accurately examined (for the benefit of mineralogiſts); and at the ſame time to explain their geneſis and connections.

We ſhall firſt define thoſe which belong to the claſs of argillacea; concerning which,

which, though the chief circumſtances have been already mentioned, I think it fit to repeat them in a compendious way, and then go on to the ſilicea.

The Gem.

A ſmall piece of this, expoſed on charcoal to the blow-pipe, does not flow; but by a very long continued flame, the hyacinth and emerald, to which we may add the aqua-marinus and the cryſolith, are ſoftened and rendered opake.

Fuſed with the mineral alkali in a ſilver ſpoon, no effervеſcence is obſerved, nor any diminution, except in the emerald, the aqua-marinus, and the cryſolith, which are as it were upon the confines of the ſchoerls; theſe are reſolved into a powder, but a refractory one, which revolves in the globule of ſalt, without any ſenſible diminution.

It is diſſolved, though ſlowly, by the microcoſmic ſalt, without any commotion. Glaſs is not tinged, unleſs by the red ruby, which colours it of a beautiful green: it remains nearly tranſparent with the reſt: with the hyacinth and emerald it grows opake upon cooling.

With borax it diſappears a little ſooner. An addition of lime aſſiſts the ſolution, which was firſt obſerved by the celebrated D. Quiſt, and agrees extremely well with its known compoſition.

The

The acids, by long digeſtion, extract a ſmall portion of the lime and iron; but if the gem has been previouſly treated with alkali, they alſo take up the clay; ſo that the ſiliceous earth alone remains undiſſolved.

In general the gems conſiſt of an argillaceous earth, which forms the greateſt part; then ſiliceous earth; then lime; and, finally, iron variouſly modified: the proportions of each ſpecies muſt be determined by a great number of experiments. It alſo remains to be determined, whether the various colours of each ſpecies occaſions any diverſity; and whether the hexagonal or octaedral priſmatic form conſtantly indicates any remarkable variety in the compoſition.

The ruby is generally of an octaedral form; ſometimes too, accidentally, ſchoerlaceous: analyſis has not yet determined the compoſition of any priſmatic ruby.

The ſapphire is ſometimes found cryſtallized like quartz; ſometimes it bears the form of an oblique parallelopiped; ſometimes, as authors relate, it is octaedral.

The topaz commonly affects either a cubic or parallelopiped form, in ſuch a manner, however, that the figure is ſeldom complete, but the number of ſides is augmented by the defect in the priſm itſelf, and particularly in the margin of the plane extremity.

The

The hyacinth alſo exhibits a tetragonal priſm, but terminated by a pyramid (tab. i. fig. 2).

The emerald is generally an hexagonal priſm, truncated at right angles.

No perſon devoted to the ſtudy of mineralogy ſhould forget of how little conſequence external marks are, eſpecially as ſtones by triture become ſhapeleſs, or at leaſt irregular. Science has much to expect from the analyſis of cryſtals, both of the ſame and different figures, although, before the compoſition can be examined, they muſt be artificially deprived of their natural form.

The ſpecies of gems is uſed to be determined by the hardneſs; and by that quality particularly, together with the clearneſs, has their goodneſs been eſtimated. The ſpinellus is particularly worthy of obſervation, which is not only powdered by the ſapphire, but even by the topaz; as alſo the cryſolith, which is broken down by the mountain cryſtal, the hardneſs of which ſeems rather to be owing to the degree of exſiccation than the proportion of ingredients. The analyſis of ſpinellus, of cryſolith, and other varieties, will ſometimes illuſtrate the true connection; otherwiſe, after the diamond, the firſt degree of hardneſs belongs to the ruby, the ſecond to ſapphire, third to the topaz, next to which comes the

the genuine hyacinth, and, fourth, the emerald.

Formerly colour was entirely confided in; but now neither can a red characterize the ruby, a blue the sapphire, a yellow the topaz, or a green the emerald.

The specific gravity varies so much, that from it nothing certain can be determined concerning the species; but the topaz is generally most weighty, from 3,460 to 4,560; the next is the ruby, from 3,180 to 4,240; then the sapphire, from 3,650 to 3,940; and, finally, the emerald, from 2,780 to 3,711; among the varieties of which last the crysolith is most ponderous.

The Garnet.

A small piece exposed to the flame flows without ebullition, sometimes into a green pellucid globule, sometimes into a black scoria.

With mineral alkali it resolves into a refractory powder so slowly, that scarce any effervescence is observed: when the iron predominates the mass grows brown.

With microcosmic salt it dissolves, without any appearance of bubbles, yielding a glass, which is green or blackish, if much iron be present.

With borax the same circumstances take place.

The acids extract scarce any thing more than

than the lime and iron; but after preparation with alkali, they alſo take up the clay, which being ſeparated the ſiliceous earth remains alone.

The ſiliceous earth forms the greateſt part; next the argillaceous; the calcareous is in ſtill ſmaller quantity.

The iron varies much; the pellucid cryſtals contain about 0,02, the opake and black ſometimes ſo far as 0,2: lead is ſeldom preſent. The cryſtals which contain tin, called zingraupen, are nearly allied to the garnets.

The form, when complete, is dodecaedral, conſiſting of equal rhombi; this may be conceived as an hexagonal priſm, terminated at each end by three rhombi. It ſometimes puts on the hyacinthine form, though but ſeldom complete, eſpecially when loaded with tin: the varieties are manifold; the internal texture is laminated, though not conſpicuouſly.

It yields in hardneſs to the topaz, but exceeds the mountain cryſtal.

The colour of pellucid garnet is red, ſometimes more or leſs verging to yellow, ſometimes to violet: that of the opake is yellow, red, or blackiſh.

It approaches neareſt to the topaz in ſpecific gravity; and, when copiouſly loaded with iron, ſcarcely exceeds it, being from 3,600 to 4,600.

The

The Schoerl.

A ſmall piece expoſed to the flame foams ſlightly, and grows ſoft, but can ſcarcely be collected into a globule, as is the caſe with the turmalin of Ceylon, which is akin to this, as alſo with the ſquamous ſchoerl, called horn-blend.

With the mineral alkali it reſolves into a powder, with a ſlight and almoſt momentary efferveſcence.

With microcoſmic ſalt it diſſolves with a ſlight efferveſcence; and on the addition of a greater quantity, the globule begins to grow opake.

With borax the caſe is the ſame; but the globule remains clear, unleſs made blackiſh by a large quantity of iron.

By long digeſtion the acids extract the calcareous earth, the metallic part, and even a great quantity of the clay; but by previous preparation with alkali, the more ſoluble parts ſeparate from the ſiliceous earth.

The ſiliceous earth is in ſomewhat greater quantity than in the garnet; the argillaceous is next in order; laſt, the calcareous. The martial ingredient forms about 0,04 in the pellucid cryſtals; in the opake, particularly the black, it ſometimes amounts to 0,2.

Its cryſtalline form, when complete, is the ſame with that of the garnet, only the priſm is more elongated; but it is very ſeldom

dom found perfect; hence the defect of apices and prifms of a greater number of fides. The angular longitudinal excavations are doubtlefs the veftiges of cryftalline fpiculæ formed at the fame time; the hornblend is generally found concreted into fquamous fquare lamellæ; the texture is fpathaceous, though not always confpicuous.

It fcarcely exceeds the mountain cryftal in hardnefs; but the prifmatic may often be cut by a knife; the fquamous always.

The colour of the tranflucid cryftals is yellow or brown, but generally green: the opake black or green.

It is nearly equal in fpecific gravity to the garnet, between 3,000 and 4,000; the clear cryftals are generally lighter.

The Zeolith.

A fmall piece expofed to the flame fwells up like borax, with the greater vehemence in proportion as it is more cryftalline; it finally goes off in a fpumous fcoria, and can very feldom be brought into a globule; a few varieties of it fhew a momentary expanfion of volume, and that without any ebullition.

With the microcofmic falt it fwells in diffolving, but flowly, and the globule remains clear.

With borax it diſſolves in the ſame manner.

The acids extract every thing that is ſoluble, without previous preparation with alkali, nay ſometimes they reſolve it into a jelly.

In this too the ſiliceous earth is more abundant than the argillaceous; the calcareous makes the ſmalleſt part; the iron ſcarcely exceeds 0,01.

The form of the cryſtals is ſeldom priſmatic; generally an imperfect pyramid; many diverge from the ſame point, with broad extremities, and often coaleſce into ſmall ſpheres.

Its hardneſs is ſeldom ſo great as to ſtrike fire with flint; generally it will not even cut glaſs.

The colour white and red, ſometimes green, very ſeldom tranſparent.

It is not of great ſpecific gravity, ſcarce exceeding 2,100.

From what has been ſaid it plainly appears, that the garnet, the ſchoerl, and the zeolith, are united in the ſame degree of affinity as the ruby, the ſapphire, the topaz, the hyacinth, and the emerald; yet in ſyſtematic arrangement the three firſt named are placed not only under different genera, but often under different orders. The hardneſs encreaſes in proportion to the clay: from the zeolith, through the ſchoerl, to the garnet, we may follow the

the natural chain, by defcending through the faxum trapp. to the marga;—in this there occurs no more than a mechanical mixture. Every clay which I have had an opportunity of examining contains filiceous particles, finer or coarfer, mixed with it, but always exceeding the weight of half the mafs, frequently amounting to 0,7, nay to 0,8; it is generally alfo mixed with iron, from 0,03 to 0,20. Let us now fuppofe the accefs of a little calcareous earth, and we fhall have the marga, which is difcovered by an effervefcence in acids, although the calcareous earth does not exceed 0,02. In the faxum trapp. analyfis difcovers the fame principles, not feparate, as in the former cafe, but united, and that not merely by induration, but by a fpecies of rude cryftallization; for the microfcope difcovers the texture to be fpiculated or granulated: fuppofe this to be reckoned among the faxa, the diftinguifhing property of which is to exhibit particles of different natures, diftinguifhable by the eye; it will at leaft be found the moft fubtile of mechanical compofitions, and conftituting a link of the chain which unites the faxa with thofe which, although compounded, are yet fo homogeneous and concreted, by the attraction of their parts, that the eye, even affifted by the glafs, cannot diftinguifh their conftituent parts; as all the integrant parts contain the fame proximate principles, and in the

 fame

ſame proportion as the whole does. To this belong the gems, the garnet, the ſchoerl, the zeolith, and other derivative earths, which Mr. Cronſtedt conſiders as primitive.

I leave it to be determined whether cryſtals may be formed without the help of any other menſtruum than water:—to me it appears very probable that any fluid vehicle, even though not a ſolvent, may be ſufficient for this purpoſe, provided the minute atoms are ſo ſuſpended in it that they may freely obey the laws of their mutual attraction. The very minute molecules exert attractions proportioned to the amplitude of their ſurfaces; a force which is deficient in larger particles. More or leſs of water alſo ſeems to enter the texture of ſtony cryſtals, although, by age and exſiccation, this is generally expelled. The foaming of the zeolith in the fire is owing to moiſture going off in the form of vapour, and no doubt it is a ſmaller quantity of this that occaſions the leſſer ebullition in the ſchoerl, ſtill leſs in the garnet, while there occurs none at all in the gems.

The petroſilices alſo contain ſiliceous, argillaceous, and calcareous earth, intimately united.

On the other hand we may ſhew the progreſs of gems, through the mountain cryſtals to the pure flints. The cleareſt cryſtals of quartz, which come from Jetland, treated with $\frac{1}{3}$ of mineral alkali (§ v.) afterwards

afterwards yielded to acids 0,06 of clay, and 0,01 of calcareous earth; ſo that the ſame principles are found as before. If any one ſuſpects that the whole of the inſoluble reſiduum, by ſucceſſive preparation with alkali, might in like manner be reſolved into argillaceous and calcareous earth, I can inform him that I have made the attempt in vain.

§ VIII. *Of the Diamond.*

As the diamond is confeſſedly the chief of the gems, commonly ſo called, I have in the preceding pages only mentioned ſuch circumſtances concerning it as ſerve to evince that it differs eſſentially from the reſt: I am far from being able to illuſtrate this difference further by a perfect analyſis, yet it may not perhaps be altogether uſeleſs to mention ſo much as I have been able to diſcover. This operation is extremely difficult, partly on account of the extravagant price, which is required for ſuch quantities as are neceſſary to make experiments which can be relied on, partly on account of the nature of the ſtone itſelf:—in order therefore to ſmooth the way, by removing obſtacles, for thoſe whom curioſity may invite to the examination of this gem, and whom circumſtances permit to proceed more eaſily than I have been able to do, I ſhall relate ſuch circumſtances as I have diſcovered.

The diamond differs from the ruby and the other gems (as has been ſaid before) by a degree of hardneſs unknown in any other production of nature, and particularly by its fugacity in a moderate heat (ſuch as is ſufficient to melt ſilver) or rather by its ſlow deflagration; for when made completely of a white heat it not only ſenſibly diminiſhes in bulk, but is ſurrounded by a little flame or cloud: but, ſo far as I know, the cubic or ſchoerl-formed diamonds have not yet been duly expoſed to fire; ſo that it remains to be diſcovered experimentally whether thoſe alſo entirely fly off, and if not they muſt loſe the name of diamonds.

The diamond, urged by a very intenſe heat, contracts a ſort of ſoot upon its ſurface.

We now proceed to examine its habits with reſpect to menſtrua.

(A) The powder fit for theſe experiments is to be had by rubbing two diamonds, entirely deprived of their external covering, againſt one another (for it is yet doubtful whether the cortical part be entirely of the ſame nature with the nucleus). Such a pulverization requires larger diamonds than it was in my power to procure upon this occaſion, I was therefore obliged to content myſelf with the examination of the powder which is for ſale. It is reported of the diamond, that it yields a powder nearly black; which is certainly true of the

 powder

powder that is ſold; but this colour is not to be conſidered as natural, as the blackneſs can be eaſily extracted by acids, the particles remaining white; ſo that the colour muſt be owing either to the inſtruments employed, or to the cortical part of the ſtone. Yet it may happen that black diamonds, which cannot be converted to other uſes, may be pulverized; and no doubt in this caſe the colour will be more fixed.

(B) This powder, when well depurated by aqua regia, eludes the force of other acids; yet with the vitriolic acid it exhibits a curious phænomenon. This menſtruum, poured upon the powder, and evaporated to a ſmall quantity, grows black, and depoſits black pellicles, which it is very difficult to dry; theſe pellicles take fire upon the approach of flame, and are almoſt entirely conſumed, at leaſt they leave ſo minute a reſiduum that the nature of it could not be examined. It is a queſtion whether this is the veſtige of a ſooty matter: I could not obſerve the ſmoke of phlogiſticated vitriolic acid proceeding from the fire.

(C) I treated the depurated powder with three times its quantity of mineral alkali, in the manner above deſcribed (§ v.): after remaining three hours in the fire the powder did not ſhew a ſenſible coheſion; however I extracted the ſoluble part by marine acid, and then attempted a precipitation with vegetable alkali; and in fact a light,

 whitiſh,

whitiſh, ſpongy, ſubſtance was thrown down, which diſſolved in all the mineral acids, but with the vitriolic produced neither ſpathum ponderoſum, nor gypſum, nor Epſom ſalt, nor perfect alum; it concreted indeed into cryſtals, but of an irregular form, eaſily ſoluble in water, which liquefied by the blow-pipe, and were then abſorbed by the charcoal; they were of an acid yet auſtere taſte.

(D) I again treated the undiſſolved powder mentioned in C with double its quantity of mineral alkali; this concreted into a firm maſs, from whence it appeared that its nature was at length ſenſibly changed. I elixated with marine acid, and by means of vegetable alkali precipitated a portion of earth ſimilar to that obtained in the former operation; but the inſoluble reſiduum ſtill floated on microcoſmic ſalt and borax in fuſion, as related in § II. A very ſmall portion of it entered the mineral alkali with effervеſcence, but was no further diſſolved; beſides, the quantity was too ſmall to be ſubjected to further experiment.

(F) Theſe experiments, although they ſhew that the analyſis of the diamond is difficult, ſhew alſo that it is not impoſſible. That there is preſent a portion of ſiliceous earth, but very cloſely united to the other principles, ſeems to be indicated by the ſlow action of the alkali: the precipitates ſhew that there is an earth ſoluble in acids, the

the nature of which remains to be difcovered by employing a larger quantity. The deflagration, the foot, and the black pellicles, fhew the prefence of an inflammable matter, unlefs we rather fuppofe them owing to heterogeneous matters adhering to the powder for fale.

(G) As the microcofmic falt feems to diffolve fomewhat of the diamond by long fufion upon charcoal, I put feveral globules much loaded with it into diftilled water, hoping that if it contained any, this, united with the phofphoric acid, would be diffolved in the water, and might then be feparated by fixed alkali: nor was I entirely difappointed; the globules fell to pieces, the infoluble part of the powder fell to the bottom, the reft was diffolved by the water, and again feparated by an alkali, but it fell very fparingly and flowly.

Thefe circumftances will perhaps give fome light to thofe who are in poffeffion of a larger quantity of adamantine materials, by which they may be enabled to complete the analyfis of this precious ftone, which, on account of its clearnefs, its hardnefs, and fplendor, is fo much valued; although by a gentle heat it is totally convertible into vapour in the fpace of a few hours; while the ruby and the other gems fuftain the fame operation without damage.

DISSERTATION XVI.

OF

THE EARTH OF THE

TURMALIN STONE.

§ 1.

THE electrical virtue of this earth has been the admiration of philoſophers, during the whole of the preſent century; and many years ſince I attempted to reduce its peculiar effects to conſtant laws: but no one, ſo far as I know, has yet undertaken the analyſis of theſe ſtones, being prevented by their ſcarcity and dearneſs. My illuſtrious friend Born removed this obſtacle for me, by ſending me, in 1778, a parcel which was got at Tyrol, and at the ſame time requeſting me to inveſtigate their primary principles. Some time after, that accompliſhed complifhed botanift, Mr. Thunberg, demonftrator in the garden at Upfal, on his return from Java and Japan, kindly brought me fome turmalins, which he himfelf had got in Ceylon, rude, and unchanged by art. I have therefore been fortunate enough, through the kindnefs of thefe gentlemen, to be able to compare the form and compofition of thefe the rareft production of the mineral kingdom, produced in the moft diftant quarters of the world. In this place I fhall only confider thofe circumftances which illuftrate the external form, the internal ftructure, and the component parts; deferring to another opportunity the confideration of their electric virtues, which fhall be confidered by themfelves.

§ II. *Vifible Qualities of the Turmalin Stone.*

Heretofore the turmalins were brought either from Ceylon or America, and no one fo much as fufpected that fuch were to be found in Europe; but two years fince, that indefatigable examinator of the Tyrol mountains, Mr. Muller, difcovered cryftals of this kind, at Zillerthal, far fuperior, both in beauty and magnitude, to any that had been ever brought, either from Afia or America; therefore we may confider them as feparated into three claffes, according to the places where they are found; and we fhall begin

begin with thoſe of the new world, which differ in certain properties from the reſt.

(A) The turmalin of Brazil is frequently ſomewhat heavier than the others, being, with reſpect to diſtilled water, from 3,075 to 3,180: they differ in colour; and I have ſeen them blue, red, and of a pellucid yellow, but generally they are green.

When rough they are of a columnar form, more or leſs regular; but frequently are of a trigonal form, conſiſting of nine ſides, as has been already deſcribed and delineated. The apices are often deficient, and their fracture is glaſſy; but ſometimes, if preſerved and examined, they are found low, and compoſed of three planes, as is explained in the Tract on the Formation of Cryſtals (§ II. E, and tab. i. fig. 3.)

The priſms, expoſed laterally to the light, are almoſt always pellucid; but when viewed in the direction of the axis a wonderful opacity prevails, and that even in the tranſverſe ſection, although it be very thin: whether this holds with reſpect to the thinneſt lamina is not yet eſtabliſhed; perhaps this, like the following, when ſufficiently diminiſhed in thickneſs, will tranſmit the rays of light.

They yield in hardneſs to the quartz, and even to the other turmalins; yet they cut glaſs, and ſtrike fire (though not eaſily) with ſteel.

(B) The turmalin of Ceylon varies a little in ſpecific gravity between 3,062 and 3,295; theſe

these seldom come to Europe unwrought: I was therefore much pleased to get those which I mentioned. The columns of three of them were whole, about three lines in length, and two in breadth: three of the sides are broad, separated by a pair very narrow, so that at first they appear trigonal; two of these prisms have apices, the solid angles of which are very obtuse, and formed of three irregular pentagons. All these circumstances agree perfectly with what has been said in A, of the turmalin of Brazil, and are made abundantly evident by tab. i. fig. 3. but the prisms are found furrowed longitudinally, a circumstance which plainly points out that other spiculæ had crystallized at the same time, and in contact with them. Marks of this kind frequently appear upon the surface of crystals; and the longitudinal furrows above mentioned are very common, particularly in the schoerls and turmalins of Brazil.

The colour of the crystals is brown, and not unfrequently almost black; but sometimes more dilute, always however more or less inclined to yellow; which may be more easily observed by placing the column transversely between a strong light and the eye. A transverse section, half a line in thickness, still appears opake, when exposed to the day-light, although the flame of a candle renders it semi-transparent and brown; but when

when made thinner, ſo far as $\frac{1}{10}$ of a line, it becomes pervious to the day-light.

I have alſo got ſhapeleſs pieces of nearly the bulk of a walnut, their ſubtile parts ſpathaceous, black, and opake; in theſe the electrical power is much weaker.

They nearly agree in hardneſs with quartz.

The electrical property of theſe ſtones ſeems to be unknown in Ceylon; and although, beyond doubt, the name *turmalin* is a word of the Ceylon language, yet, under the ſame name, Dr. Thunberg got ſtones of various colours, and various genera, of which, among eight varieties, not one acquired the electric quality by heat, altho' I frequently made the experiment. Dr. Thunberg alſo informed me, that, in the genuine language of the country, the word ſignifies black cryſtals; that they are little eſteemed, and are pounded and formed into globules to ſerve the purpoſe of buttons.

(c) The turmalin of Tyrol has been ſo exactly deſcribed by the learned diſcoverer, with reſpect to external appearance, that nothing can be added; but, for the ſake of compariſon, it will be proper to repeat the principal circumſtances.

The ſpecific gravity is 3,050, that is leſs than any of the preceding.

The cryſtals are ſometimes three inches in length, and exceed five lines in diameter, partly looſely diſperſed among, partly firmly united to, a ſteatite, mixed with particles

of

of mica, not unlike the olla Jetlandica. What the matrix of the other turmalins may be, is yet unknown; but that of the Tyrol turmalin form either veins or nuclei in granite.

The figure is prifmatic, confifting of nine fides, fometimes terminated by three pentagons like that of Ceylon, but in general the apices are wanting: fometimes, however, though very feldom, the pyramids are found very much acuminated, with nine fides; therefore, in general, all the known turmalins agree in form; but, fo far as I know, the complete fchoerl form (tab. i. fig. 1.) has not yet been feen among them by any one; — a form which, even among the fchoerls themfelves, is extremely rare.

Such of the Tyrol cryftals as I have examined are without the longitudinal fulci; but the furface, when accurately examined, fhews a flight afperity, owing perhaps to the fpicular form of the furrounding matrix; but the tranfverfe chinks, generally obfcure, are found in thefe and the preceding, as well as in the fchoerls.

The colour occafioned by reflex light is footy, or of a brownifh black, but that by refracted light of an obfcure yellow; a thin tranfverfe fection appears opake, but when the thicknefs is fufficiently diminifhed, it at length tranfmits green rays, as the celebrated Muller firft obferved, and as I have myfelf feen, the account is true. The Ceylon and Tyrol turmalin therefore agree in in this, that by extreme tenuity a paſſage is made for the light; but they differ with reſpect to the rays, which are tranſmitted.

(D) Many years ſince I obſerved that a variety of the ſchoerl, black, opake, of a complete figure, which came from Umæan Lapland, by a due degree of heat acquired electrical properties. Upon multiplying experiments I found the ſame thing to take place in ſeveral ſchoerls of Sweden, both nonagonal and ſpicular, of very irregular forms—theſe were all totally opake; and heretofore I have not obſerved that property to take place in any that was pellucid.—How this electricity may be excited, and its nature explored, I defer to another place, where this matter ſhall be expreſsly conſidered.

§ III. *Habits of the Turmalin expoſed to the Blow-pipe.*

(A) A ſmall piece, the ſize of a grain of muſtard, expoſed upon charcoal to the apex of the flame, quickly grows red, and that without any decrepitation or other viſible change: but if the action of the flame is continued for ſome minutes, it ſoon grows white, foams almoſt like borax, and, upon continuing the fire, is reduced to a globule; a larger piece fuſes with difficulty, but yields an inflated ſpongy white ſcoria.

This is the caſe with the turmalin of Tyrol and Ceylon when cryſtallized; but the black and ſhapeleſs pieces ſwell but little, and the marks of ſcorification which appear on the ſurface are brown, not white; that of Brazil cannot be formed into a globule, but exhibits a puſtulous ſcoria.

(B) The microcoſmic ſalt, fuſed upon the charcoal, attacks a ſmall quantity of turmalin with a ſlight efferveſcence, which is yet ſoon at an end; and there remains a ſmall corpuſcule, almoſt tranſparent, and therefore ſcarce perceptible, until after the globule grows cold: this reſiduum is diſſolved with great difficulty, but the reſt of the vitreous maſs ſurrounding it is found clear and tranſparent, which grows green on a farther addition while hot, and milky on cooling, chiefly occaſioned by the undiſſolved particles. All the varieties in this reſpect are the ſame, except that the black and opake occaſion a brown colour.

(C) Borax takes up the turmalin almoſt in the ſame way, but generates heat more diſtinctly, and diſſolves the ſtone more powerfully, ſo that it hardly contracts a perfect opacity, except the black turmalin, which added in ſmall quantity changes the tranſparency to a yellow brown, but in larger quantity to a black opacity.

(D) Mineral alkali takes up the turmalin in fuſion with efferveſcence, but a leſs conſpicuous one than that excited by quartz: when

when a ſmall portion of the ſtone is added, it is broken down into a powder, but is imperfectly diſſolved: the black opake turmalin makes the globule brown.

(E) The turmalin approaches next to the ſchoerl in the habit juſt deſcribed; the latter is, however, more completely diſſolved, and with more evident ebullition, by the microcoſmic ſalt, and alſo effervesces more vehemently with mineral alkali.

§ IV. *Habitudes of the Turmalin with Acids.*

(A) Three times the weight of concentrated vitriolic acid, poured on 100 lb. of ſubtile powder of turmalin, ſeparated by elutriation, and expoſed to diſtillation in a ſmall retort until the bottom of the glaſs grows red hot, yields a reſiduum, which being boiled in diſtilled water, collected, dried, and weighed, is found to have loſt about 16 lb. The three known varieties are, in this reſpect, ſcarce found to differ a pound or two.

The water which has extracted the ſoluble part, with a lixivium of burned blood yields Pruſſian blue; and, the iron being thus precipitated, on addition of fixed alkali a white powder is thrown down, which, with vitriolic acid, forms gypſum; which may again be decompoſed by acid of ſugar: the acid has therefore been only loaded with iron and lime.

The

The acid collected in the receiver is found to be purely vitriolic.

The elixated residuum, examined by the blow-pipe, swells and shews almost the same habits as the crude turmalin.

(B) The nitrous and marine acids also extract iron and lime; but in other respects have no greater effect than the vitriolic, for the residuum still remains compound; the surface therefore is not sufficiently encreased by the mechanical pulverization, so that the menstrua may be able to separate the component parts: however, the method which I followed in decomposing the gems succeeds in this case extremely well.

§ V. *Proximate Principles of Turmalin.*

(A) I treated a very subtile powder of turmalin in the same manner as the gems, with this difference, that I employed an equal quantity of mineral alkali, spontaneously calcined, and kept the mass ignited only for an hour and a half.

(B) Upon cooling, the mixture is found colliquated, its surface convex, tuberculated, of the colour of wax, but internally spongy, and of a green colour, which is of a deeper hue, as it approaches the bottom, to which it adheres. The mass, when sufficiently loosened, is covered at the bottom with a black crust, which is carefully separated and weighed.

(c) The reſt of the proceſs was conducted as deſcribed on the Earth of Gems, F and N; it would therefore be ſuperfluous to deſcribe it again. Theſe operations yielded the following concluſions concerning the quality and proportions of the conſtituent parts in an aſſay hundred; *viz.*

The turmalin of Tyrol.

argillaceous earth - -	42
ſiliceous earth - -	40
calcareous earth - -	12
iron - - - -	6

Turmalin of Ceylon.

argillaceous earth - -	39
ſiliceous earth - - -	37
calcareous earth - -	15
iron - - - -	9

Turmalin of Brazil.

argillaceous earth - -	50
ſiliceous earth - - -	34
calcareous earth - -	11
iron - - - -	5

(D) By argillaceous and ſiliceous earths, I here underſtand thoſe earths freed from all heterogeneous matter; but the calcareous earth appears to be nearly ſaturated with aerial acid, as otherwiſe a greater defect is obſerved than can be ſuppoſed in an accurate operation. That no efferveſcence takes place with acids is eaſily accounted for, when we conſider

conſider that only a very minute portion of calcareous earth adheres ſo very cloſely to the other conſtituent parts, that it has ſuffi-cient hardneſs to ſtrike fire with ſteel: the iron is dephlogiſticated, and the crude tur-malin does not ſhew the leaſt ſign of de-tonation with nitre.

As to the proportions of the conſtituent principles, I have ſet down ſuch as experi-ments ſuggeſted; but it is neceſſary to take the medium of a number of experiments, as nature does not obſerve ſo exact a propor-tion in the admixture of the principles of bodies, but that ſometimes there may be ſome hundredths too much or too little; beſides, a ſeries of operations (notwith-ſtanding the greateſt poſſible accuracy) will ſometimes add a little weight, or ſome-times diminiſh, which is particularly ſen-ſible when very ſmall quantities are uſed. Thus, in the preſent inſtance, I have not yet been able to ſubject to experiment more than a few aſſay pounds: in theſe experiments I conſtantly found the ſame ingredients, but the proportion of them required ſome correction. The difference of habits diſcovered by the blow-pipe ma-nifeſted ſome difference between the Tyrol and Ceylon turmalin; but whether the above proportions be exact, remains further to be examined.

(F) That water enters the compoſition may be gathered from their undergoing the ſame ebullition in fuſion as the zeolith does, which certainly contains water; but the quantity of matter to be examined only permitted me to make one trial with this view. I kept 100 lb. of Tyrol turmalin groſsly powdered for half an hour in an obſcure red heat; but upon cooling found no difference in weight, nor did I expect any, as a white heat is neceſſary to fuſion: I therefore encreaſed the fire to a ſufficient degree, but the fragments of turmalin were agglutinated to the crucible, nay, had entered into a ſort of union with it; I therefore made the experiment in another, which was tedious and troubleſome:—I took 25 aſſay pounds of fragments of turmalin, each of which I ſeparately reduced to white ſcoriæ by the blow-pipe, but I did not find that the weight was ſenſibly diminiſhed; a proof that there is either no water at all, or only a very ſmall quantity.

§ VI. *The Place belonging to the Turmalin in a Syſtem of Mineralogy.*

Being acquainted with the nature and proportion of the earthy principles which enter into the compoſition of the turmalin, we cannot heſitate to place it among the argillaceous ſpecies, ſince the chief part of it is conſtituted by this earth, which, even when it is preſent in ſmaller proportion, communicates

communicates its peculiar properties to the whole maſs.

In the gems we find the ſame principles, and clay in greater proportion than any other earth: the turmalin can ſcarce be referred to this claſs, becauſe its ſtructure is ſo much looſer.

The phænomena it exhibits, when treated with the blow-pipe, approach nearly to thoſe of zeolith; but of this ſiliceous earth conſtitutes the principal part: and the conſtituent principles cohere ſo weakly that acids are capable of extracting them without any previous treatment with fixed alkali, and the heat of diſtillation of expelling moſt of the water. It is more cloſely allied to ſchoerl; for the turmalin not only reſembles this in the form of its cryſtals, and the phænomena it preſents, both with heat and ſolvents, but alſo ſometimes in being electrical, a property which ſhall be particularly examined in the ſequel; it however differs in containing more ſiliceous earth, and ſome other circumſtances before noticed (§ III. E).

DISSERTATION XVII.

OF

THE FULMINATING

CALX OF GOLD.

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§ I. *Historical Introduction.*

ALTHOUGH the wonderful fulminating property of gold was known at leaſt in the 15th century, it has not yet been examined by philoſophers ſo as to determine with certainty the cauſe of the prodigious noiſe and ſtupendous exploſive force; yet in this exploſion there occur phænomena highly worthy of attention—phænomena which not only indicate very ſingular properties, but are of ſuch

ſuch a kind that the cauſes of them, well underſtood, muſt certainly throw great light upon the theory of chemiſtry. The following experiments, which are partly new, and partly ſuch as have been deſcribed by others, but carefully reviſed and corrected, will I hope tend to illuſtrate the ſubject. But before we enter upon them it will be proper briefly to relate the attempts of others, who have made this buſineſs their particular ſtudy.

Whether or not the ancient alchemiſts were acquainted with the fulminating property of gold, we are ignorant; their arcana being involved in an enigmatic and obſcure ſtile. Baſil Valentine is perhaps the firſt who has clearly deſcribed the method of communicating this property to gold: he directs the metal to be diſſolved in aqua regia made with ſal ammoniac, and then precipitated by vegetable alkali, to be twelve times waſhed with water, and finally dried in the open air, where the ſun's rays cannot reach the powder; he forbids it to be dried over a fire, as it explodes with a gentle heat, and flies off with inconceivable violence; but he has not diſtinguiſhed this calx by any peculiar name.

Many chemiſts afterwards performed this operation, but here and there we obſerve ſome ſmall difference.—O. Crollius calls it *aurum volatile*, and is ſcarce willing to have it dried, even though carefully, and in balneo maris; but above all forbids the ſtirring it with an iron ſpatula. J. Beguin added the epithet *fulminating*, which has been ſince generally adopted; although we ſometimes meet with the terms *ſclopetans* and *ceraunochryſon*.

The neceſſity of employing volatile alkali in this operation was but little regarded until the preſent century; for Hellot tells us, from Groſſe, that gold diſſolved in a mixture of nitrous and marine acid, fulminates better when the volatile is uſed than when the vegetable fixed alkali is employed; but that if the menſtruum be made with ſal ammoniac, the latter precipitate is beſt. Zwelf calls the gold precipitated by fixed alkali, without the fulminating property, aurum mutum. Ettmuller and Hoffman found that precipitated by volatile alkali always fulminating.

Becher found the fulminating powder, when well waſhed, heavier than the gold employed by $\frac{1}{5}$; Lemery by $\frac{1}{4}$; and Jungken by $\frac{1}{3}$: it is doubtful whether Barner ever made the experiment, as he affirms that in order to produce the beſt effect it ſhould not be waſhed with water (compare § x). Many alſo, after him, have thought that by boiling in water the fulminating property is deſtroyed, or at leaſt diminiſhed; the celebrated Beaumé was the firſt who detected that error.

That

That water loaded with fixed alkali when boiling takes away all the explofive power, is afferted, if I miftake not, by all the moderns, following the author of Homer's Golden Chain. Kunckel found this property deftroyed by vitriolic acid. Rolfincius, and others, contend that marine acid has the fame effect; and Mr. Spielman extends that faculty to all the acids, even to vinegar: yet Caffius relates that aurum fulminans exploded moft violently when marine acid dulcified was diftilling from it. Bafil Valentine attempted, not without fuccefs, to fubdue the fulminating property by means of fulphur.

A fingle fcruple of aurum fulminans explodes, as Crollius afferts, with more force than half a pound of gun-powder, and propagates its action downwards; yet H. F. Teykmeyer frequently fhewed in his lectures that it would throw a florin upwards above fix ells; and the fame effect had been obferved by many others before him.

A great number of experiments were made before the Royal Society at London, in order to determine the comparative forces of thefe two powders:—equal parts of gun-powder and of aurum fulminans were included in iron globes, which were placed among burning coals; thofe which contained the former were burft with violence, while the other remained perfectly filent. But if the globe containing the gun-powder did

did not exceed the bignefs of a pea, the globe remained unhurt, although the contents had been inflamed.

Many unfortunate accidents however fhew that the greateft caution is neceffary in handling aurum fulminans: Orfchal relates, that this powder, ground in a jafper mortar, had by its explofion burft the mortar into a thoufand pieces: the celebrated Dr. Lewis gives an inftance of the fame in England; nay, Dr. Birch tells us that by an explofion of this kind doors and windows had been violently torn to pieces: but Mr. Macquer gives a very melancholy detail of a misfortune which happened in his own prefence:—a perfon of 22 had put fome aurum fulminans into a phial, but unfortunately did not obferve that a few particles adhered to the neck; upon fhutting it therefore, as is ufual, by twifting the glafs ftopper, the few particles exploded with fuch force as to throw the young man among the furnaces of the laboratory, with the lofs of both his eyes, occafioned by the fplinters of the glafs.

The fentiments of chemifts concerning the caufe of the fulmination differ very much; the opinions of thofe who fpeak in words fo obfcure that it is fcarce poffible to reduce them to fenfe, we fhall omit; the reft may be divided into four clafles, fome afcribing it to an aerial, fome to a faline, fome to a fulphureous principle, and finally, there

there are others who ſuppoſe it to depend upon ſeveral of theſe united.

F. Hoffman attributes it to humidity and an elaſtic vapour dilated by heat; but the celebrated Dr. Black affirms it to be owing to fixed air copiouſly and ſuddenly ſet at liberty. A. Peterman aſſerts this power to depend upon the union of the ſolar principles with nitre; but others, and indeed the moſt of the moderns, ſubſtitute a ſpecies of nitre totally volatile, which is commonly called *nitrum flammans*. Caſſius ſpeaks of ſulphureous particles of gold which are diſcharged from the bond of ſalts, as being ſubſtances of an oppoſite nature, by means of the fire; and, upon getting looſe, give as violent a concuſſion to the air, as ſulphur and nitre in common gun-powder; but very lately M. Beaumé propoſes as the cauſe, a nitrous ſulphur deflagrating violently; and ſupports this opinion with many ſpecious arguments. Notwithſtanding all theſe explanations, many philoſophers are ſtill of opinion, that the phænomenon is not yet accounted for: ſuch are Boerhaave, Macquer, Spielman, and others.

If in our days a certain fragor vibergenſis were neceſſary, a very violent one might be beſt obtained by means of this calx of gold; for no ſubſtance hitherto known explodes with a louder noiſe. Dr. Lewis compares the report occaſioned by gun-powder to the ſound of a long and lax cord; and that of of aurum fulminans, to that of a ſhort and tenſe one. But in mines it cannot be ſubſtituted for gun-powder, as, when it is cloſe ſhut up, it is reduced without noiſe or violence, as we have ſeen before; beſides, this powder muſt be fired by heat, and not by ſparks.

The celebrated Stahl ſays, that aurum fulminans, treated with ſulphur, as hereafter deſcribed, is uſed as a pigment by goldſmiths and enamellers. Doſſie mentions this as a valuable ſecret.

Formerly, three or four grains of this powder were given as a diaphoretic of extraordinary power, as we are told by Crollius and Beguin. Rolfincius relates an example of its cathartic virtue: his words are theſe, *Illuſtris regiæ Suecicæ militiæ generalis Pannerius* (doubtleſs *Banner*) *graviſſimo colico dolore infeſtatus, clyſteribus aliquot officium non facientibus, habuit melius, commota alvo, aſſumptis auri fulminantis granis* 6 *in cochleari pleno vini Malvatici.*

§ II. *Preparation of Aurum Fulminans.*

This powder may be prepared in two different ways; for either the gold is diſſolved in a menſtruum compoſed of nitrous acid and ſal ammoniac, and the ſolution precipitated by a fixed alkali, or the ſolution is performed by aqua regis made without ſal ammoniac (which may be done in various

rious ways) and the precipitation effected by volatile alkali. Aqua regis without ſal ammoniac may be prepared by mere mixture of nitrous and marine acid, or by nitre diſſolved in marine acid; or, finally, by ſea-ſalt diſſolved in nitrous acid. It is obvious, that inſtead of nitre or ſea-ſalt, other ſalts containing theſe acids may be employed. *Menſtruum ſine ſtrepitu* was a name formerly given to a liquor conſiſting of a little water with nitre, ſea-ſalt, and alum, in which gold-leaf was diſſolved by triture; in this caſe the acid of the alum expels the other acids, which therefore, by their union, form common aqua regia.

By whatever method the gold be diſſolved and precipitated (provided the volatile alkali is preſent, either in the menſtruum or the precipitant) a yellow precipitate is obtained, which, when well waſhed in water, and cautiouſly dried, is commonly called aurum fulminans. The weight of the calx, well waſhed and dried, exceeds that of the gold employed, by about $\frac{1}{5}$.

The diſſolved gold is more readily precipitated by volatile than by fixed alkali.

§ III. *Properties of the fulminating Calx of Gold.*

The phænomenon which has chiefly rendered this powder famous, and has given occaſion to the name, is the prodigious noiſe occaſioned

occaſioned by the exploſion of a few grains expoſed to heat in a metal ſpoon, either over a candle, coals, or a red hot iron; or by any other means ſufficiently heated. How this phænomenon takes place, we ſhall ſee hereafter.

(A) A degree of heat between 120° and 300°, the degrees at which the nitrous and vitriolic acids boil, is ſufficient for this purpoſe; but whether the ſolar rays, without concentration, can produce the ſame effect, as ſome perſons aſſert, I have not yet been able to determine; but am inclined to doubt of their poſſeſſing ſuch efficacy, unleſs the aurum fulminans be extremely well prepared; but if the maſs be inſpected juſt as it is about to explode, in the very inſtant preceding the exploſion no other change is obſerved than its colour verging to black, upon which it inſtantly is diſperſed with an obſcure flaſh, and a wonderfully acute ſound: the ſame effect is obſerved whether the powder be ſurrounded by common air, or aerial acid.

(B) By ſimple triture, or percuſſion alone, this powder is inflamed, and explodes with great violence, whence melancholy accidents have ſometimes happened; but every ſort of aurum fulminans is not ſuſceptible of exploſion by theſe means. By boiling in pure water, or (which is better) in an alkaline lixivium, or (which is beſt of all) by a due degree of calcination, it is rendered ſo prone to inflammation, that by the electric ſpark, nay often by the ſmalleſt agitation with a piece of paper, it explodes; the common aurum fulminans is alſo exploded by the electrical ſhock.

(c) A portion weighing from 10 to 12 grains of aurum fulminans, exploded on a metal plate, perforates and lacerates it; a ſmaller quantity forms a cavity in the plate; and a ſtill ſmaller only ſcratches the ſurface; an effect which is never produced by gun-powder, though in much larger quantity.

(D) A weight laid upon the powder is thrown upwards in the moment of exploſion; and if it be of ſilver, it is found gilded with a yellowiſh ſpot. In the ſame way is marked the ſupport, if it be made of ſilver or copper.

Beſides, a large grain, advanced near to the ſide of the flame of a candle, blows it out with violent noiſe; and a few ounces exploding together, by incautious drying, has been known to ſhatter the doors and windows of the apartment: hence it is evident, that aurum fulminans exerts its force in all directions; yet it cannot be denied, that it ſtrikes bodies with which it is in contact more violently than thoſe which are at a ſmall diſtance, though in its vicinity: thus, if a ſmall portion of it explodes in a paper box, it lacerates only the bottom, unleſs the top be preſſed down cloſe, in which

which caſe it perforates both the top and bottom.

(E) When carefully and gradually exploded in a glaſs phial or a paper box, it leaves a purple ſoot, in which are found many particles of ſhining gold; nay, if the quantity exploded be large, ſeveral grains remain totally unchanged; for it is only the ſtratum next to the heat which is inflamed, as may be ſhewn by an eaſy experiment, namely, if the fulmination be performed over a large ſurface of burning coals; for in that caſe a number of decrepitations will be heard, occaſioned by grains of the aurum fulminans diſperſed in a perfect ſtate by the exploſion of the inferior ſtrata.

(F) When moiſt, it does not explode all at once, but each grain, in order as it becomes dry, decrepitates in a manner ſimilar to common ſalt.

(G) In glaſs veſſels cloſed, or with their mouths immerſed in water to prevent breaking, a moderate quantity explodes indeed, but with a very weak noiſe, ſo as ſcarcely to be perceived; but in the moment of exploſion, an elaſtic fluid breaks forth, which, when cool, occupies about ſeven inches, if half a drachm of the powder has been uſed: this air extinguiſhes flame, deſtroys animal life, rejects pure water, and does not even precipitate that which contains lime in ſolution.

(H) In

(H) In metallic veſſels of ſufficient ſtrength and perfectly cloſed, aurum fulminans, expoſed to heat, is reduced ſilently, and without any marks of violence: if the acceſs of air be only partially prevented, the metallic veſſels are more violently acted upon; but if they are of ſufficient ſtrength, and very ſmall chinks afford vent to the air, the ſmoke indeed penetrates through, but gently, and without burſting, as I twice experienced in about half a ſcruple of this calx, with which I filled a braſs roſe, and ſtopped the aperture with a ſtrong ſcrew; for in this caſe the vapour made its way through the pores with a hiſſing noiſe.

§ IV. *Means by which the fulminating Property may be deſtroyed.*

This may be effected by various methods, and that even without additament.

(A) For inſtance, by fire alone, ſlowly and cautiouſly increaſed: let a degree of heat at firſt be employed near to that which uſually occaſions the exploſion; this muſt immediately be ſlackened a little, and thus alternately be increaſed and diminiſhed: upon continuing this operation a long time, the aurum fulminans gradually becomes capable of reſiſting a fire more and more intenſe, at length grows of an obſcure black, and loſes all its fulminating properties: this experiment requires conſiderable patience; for, unleſs the fire be ſkilfully regulated, and the ſmalleſt agitation and friction avoided, the powder explodes at once with its uſual vehemence, and flies off in the form of vapour.

(B) This effect is more commodiouſly obtained by the addition of a dry ſubſtance of any ſort, provided it be well pulverized, and intimately mixed with the aurum fulminans by trituration, ſo that the particles of the latter may be ſeparated as much as poſſible; for this being done (which may be eaſily tried with ſmall portions) the mixture may ſafely be expoſed to the fire.

Sulphur has been long uſed for this purpoſe in the following way:—let powder of ſulphur be mixed with an equal weight, or half its weight, of aurum fulminans, then melted for a ſhort time with a gentle heat without ſmoke, after this with evaporation, and, finally, burned with deflagration: this is done much more eaſily by putting the mixture by degrees into a crucible previouſly ſo heated, that the ſulphur will flame upon touching it; for in this caſe, although a few grains decrepitate, they are not diſperſed. This may be effected with ſtill greater eaſe, by adding the aurum fulminans gradually to the ſulphur in fuſion.

The ſalts, either alkaline or middle, are ſufficient for this purpoſe, and are uſed with great advantage, becauſe they may be afterwards ſeparated by ablution.

This operation ſucceeds alſo with the earths, nay, with concentrated vitriolic acid, and other liquors, as we ſhall afterwards ſee (§ VIII. and IX). In a word, aurum fulminans is deprived of its fulminating property, if expoſed to a degree of heat ſufficient to cauſe the exploſion, if at the ſame time the fulmination be prevented by any means whatever, even by external force.

§ V. *Chief Opinions concerning the Cauſe of the Exploſion.*

Various explanations of this exploſive property are to be found among chemiſts; ſome of which, being delivered in an unintelligible manner, we may properly paſs over, and conſider the others as diſtributed into four claſſes; for philoſophers have thought, that this wonderful phænomenon might be attributed to a ſaline, a ſulphureous, or an aerial principle, or, finally, to many of theſe jointly; yet ſome there are, who with juſtice conſider all the explanations hitherto given as inſufficient.

§ VI. *Different Opinions concerning the Cauſe, ſuppoſed to be ſaline.*

Thoſe who attribute the fulmination to a ſaline principle, do not yet agree with regard to the ſpecies of ſalt.

(A) Some consider the salited fixed alkali (which is called sal digestivus) adhering to the calx, and decrepitating in the heat, as the cause of this phænomenon; but these gentlemen do not consider, that this salt is neither present nor regenerated, when the gold dissolved in nitrous acid, containing sal ammoniac, or in a mixture of nitrous and marine acids, is precipitated by volatile alkali; and, besides, if the latter of these solutions be precipitated by fixed alkali, the precipitate is not fulminating, though the digestive salt in this case is present.

(B) Others have recourse to common nitre, which is known to detonate with phlogiston: but here the same difficulties occur, for neither is nitre always present in the preparation of aurum fulminans, nor, when it is present, is the calx always found fulminating; besides, this salt does not detonate with the calx of gold, but on the contrary (by the method described § IV.) serves to reduce it.

(C) The nitre, called nitrum flammans, seems to be very different in its nature; this salt consists of nitrous acid saturated with volatile alkali; and, from what has been already said, the presence of this substance in aurum fulminans is obvious; besides, it possesses the property of detonating, without the addition of phlogiston; and, besides, we are told by authors, that the vitriolic acid and fixed alkali destroy the fulminating property; the former becauſe it is more powerful than the nitrous acid, and the latter becauſe it expels the volatile alkali. This opinion therefore carries with it an appearance of probability, and almoſt all the moderns have embraced it. In order however to acquire a certain knowledge of this matter, if poſſible, I inſtituted a number of experiments, the chief of which I ſhall now relate.

§ VII. *Fixed Alkali does not deſtroy the fulminating Property by the Via humida.*

The fixed alkali does indeed deprive gold of its fulminating power, by fire, as deſcribed in § IV. but in that caſe it acts in no other way than any other matter interpoſed between the particles: but whether it acted in virtue of its alkaline quality, was tried in another way.

(A) Six parts of alkali of tartar were therefore well triturated in a glaſs, with one of the calx, and a few drops of water. This being done, a little more water was poured on, and all the liquor evaporated in a digeſting heat. During this operation no veſtige of urinous ſmell could be perceived: the mixture, when dried, and freed from the ſaline parts by ablution, not only fulminated, but with a noiſe far greater than uſual.

(B) The ſame experiment was made in another way; namely, one part of aurum fulminans was boiled for half an hour in 200 of cauſtic lixivium; but its power was rather increaſed than diminiſhed by this: water was added, to prevent the lixivium from acquiring too great a degree of heat, which would of itſelf deſtroy the fulminating property (§ IV.)

One circumſtance I ſhall remark, *viz.* that no difference of efficacy was obſerved, whether the calx was precipitated from its menſtruum quickly or ſlowly.

§ VIII. *Whether Acids deſtroy the fulminating Property.*

As vitriolic acid requires near thrice a greater degree of heat to make it boil than pure water, it is no way ſurprizing that boiling in this acid ſhould deſtroy the fulminating quality, as before obſerved: but, in order to determine whether that was the true and only cauſe, the acid was ſo far diluted with diſtilled water, that it could not ſuſtain too high a degree of heat, and the aurum fulminans boiled in it for half an hour, when, after being well edulcorated, it exploded as uſual: nor does it, when triturated and digeſted with the ſtrongeſt vitriolic acid, loſe any of its power, but by boiling many particles acquired the metallic ſplendor of gold.

(B) The marine and nitrous acids, when boiling violently, poſſeſs a greater degree of heat

heat than boiling water, but inferior to that which is neceſſary for fulmination; hence it happens, that the latter of theſe fluids not only fails of deſtroying the fulminating power, but the precipitate, while wet with this, decrepitates in the ſame way as if penetrated by water.

(c) But the marine acid diſſolves this calx more eaſily, and upon evaporation almoſt always reduces a part; for this menſtruum naturally contains phlogiſton, which, by means of ſuperior attraction, it is obliged to yield to other bodies: but the ſolution itſelf, precipitated by fixed alkali, yields a calciform and fulminating gold. Whatever is not diſſolved by digeſtion, when well edulcorated ſeems to have loſt ſcarcely any thing.

(D) Upon adding vinegar, and diſtilling to dryneſs, the fulminating power is found to be deſtroyed: this however is only to be underſtood of the reſiduum, either not edulcorated, or reduced by means of heat.

§ IX. *The fulminating Property may be communicated to Gold, without the Intervention of nitrous Acid.*

In order to diſcover whether the nitrous acid be altogether neceſſary; and alſo how the proceſs would ſucceed without the marine acid, the following experiments were undertaken.

(A) A calx of gold (not fulminating) boiled in vitriolic acid a little diluted, yielded a yellow ſolution, for the precipitation of which a large quantity of cauſtic volatile alkali was neceſſary: the precipitate was ſmall, but, after being edulcorated, fulminated by heat.

(B) Another portion, boiled in nitrous acid perfectly freed from marine acid by means of ſilver, yielded, though not without boiling violently, a red ſolution, of the ſame colour as that of platina in aqua regia: this, upon the ſimple addition of water, let fall a calx, which, digeſted with cauſtic volatile alkali edulcorated and dried, exploded in the heat in the ſame way as gold precipitated from the nitrous acid by cauſtic volatile alkali, when waſhed and dried.

(C) Of all acids the muriatic beſt diſſolves the inert calx of gold; even without heat it diſſolves it readily: a ſolution of this kind was precipitated by volatile alkali, as before, and the ſediment, when waſhed and dried, fulminated as uſual.

§ x. *The Fulmination is not effected by a Nitrum Flammans.*

In order the better to underſtand the detonating property of the nitrum flammans, let a portion of it be put into a cold glaſs, then let the heat be raiſed as quick as poſſible,

ſible, yet no detonation enſues, but the ſalt is reſolved into vapour, and flies off: let the glaſs be hot at firſt, and the ſalt will liquefy, but not detonate; but if it fall upon an ignited glaſs, it kindles and deflagrates, with a noiſe and a yellow flame: it is in vain therefore to aſſign this ſalt as the cauſe of the fulmination.—Beſides,

(A) The ſound of this detonation is not at all correſpondent to that occaſioned by fulmination; but let us ſuppoſe it to be encreaſed by the weight of the ſuperincumbent particles of gold, which prevent it from breaking forth, until the tendency to exploſion, increaſing more and more, becomes at length able to remove the obſtacle: but ſimple detonation, unimpeded, requires a heat equal to ignition; when impeded it ſhould therefore require a greater degree: now aurum fulminans requires a much ſmaller heat, therefore ſome other cauſe beſides detonation muſt operate here.

(B) The precipitate of gold, which does not fulminate, I have endeavoured to unite by dry triture with nitrum flammans; but by this method could obtain nothing more than a powder which crackled in the heat.

(C) As the ſalt is ſo eaſily ſoluble in water as readily to attract humidity from the atmoſphere, I thought that (if preſent in aurum fulminans) it might be ſeparated by boiling: one part of it was therefore boiled with 600 of diſtilled water for a whole hour,

hour, and after the interval of a day the ſame was boiled with 600 parts of freſh water for the ſame length of time, but in vain, for the powder fulminated with as great violence as before.—We may here obſerve the gradual efficacy of water: thus, if gold precipitated from the menſtruum be not edulcorated, it ſcarcely fulminates at all; if waſhed a little with cold water it explodes indeed, but with a very obtuſe ſound, and a diffuſed flaſh; but if it be waſhed with a large quantity of water, or with hot water, it occaſions an acute ſound and an obſcure flaſh. The efficacy of the water, when brought to this degree, is neither encreaſed nor diminiſhed by boiling, as far as the ear can judge, which we are obliged to truſt to, ſo long as we are deſtitute of a more accurate meaſure.

No one can wonder at the deſtruction of the fulminating quality in Papin's digeſter, upon conſidering the degree of heat which it there ſuſtains (§ IV).

(D) Gold diſſolved in dephlogiſticated marine acid, and precipitated by volatile alkali, poſſeſſes the fulminating property, though nitrous acid has never touched it. If any one imagines that gold diſſolved in aqua regia can never (by the humid way) be perfectly freed from nitrous acid, he muſt at leaſt confeſs that that acid is altogether abſent when dephlogiſticated marine acid is employed to diſſolve the gold: this acid contains

contains a certain quantity of phlogiston, which it is obliged to yield to manganese, and then becomes a yellow vapour, which dissolves all metals, by taking from them that quantity of phlogiston which would otherwise impede the solution; and the acid itself is thus restored to its natural state, and the combinations thus formed yield metallic salts containing a perfect marine acid.

From all this we conclude, that, even though the nitrum flammans were, which it is not, sufficient to explain the phænomena, yet it could not be admitted as the true and efficient cause.

§ XI. *Volatile Alkali necessary to the Fulmination.*

(A) In order to discover what the volatile alkali contributed to this effect, a non-fulminating precipitate was digested for some hours in caustic volatile alkali, afterwards edulcorated and dried: this fulminated perfectly.

(B) Lest some suspicion should remain, of a remnant of the aqua regia adhering to the precipitate, notwithstanding the edulcoration, the experiment was repeated in this way: after digestion for 24 hours in vitriolic acid, the precipitate was washed in pure water, then immersed in aqueous and spirituous solutions of alkali, both mild and caustic; but the event was the same.

(C) An

(c) An inert calx of gold, by ſimple digeſtion in a ſolution of any ſalt containing volatile alkali, whether the ſaturating acid be vitriolic, nitrous, or marine, poſſeſſes the fulminating property. The golden calx is found increaſed in weight about 0,2, and the reſidua of the ammoniacal ſolution contain a ſuperabundant acid: therefore the non-fulminating calx of gold is capable of abſtracting a certain quantity of volatile alkali from the ammoniacal ſalts; which portion may again be ſeparated by diſtilling the aurum fulminans well waſhed with vitriolic acid; for in the neck of the retort a vitriolated volatile alkali is found ſublimed.

(D) Finally, we ſhould recollect that gold cannot receive the fulminating property without volatile alkali (§ 11).

§ XII. *Whether the Fulmination be effected by a Sulphur.*

Moſt of the ancient chemiſts, and not a few of the moderns, ſpeak of a certain ſolar ſulphur, nay, ſome contend that gold is wholly a ſulphur; hence they derive the effects produced in the preſent caſe, endeavouring to perſuade themſelves and others that here the ſame principles co-exiſt as in gun-powder and pulvis fulminans, namely, ſulphur, nitre, and tartar. But opinions like theſe, at once ſubtile and obſcure, we ſhall leave involved in their own darkneſs.

The

The following obſervations will ſhew that it is without reaſon any ſulphur is ſuſpected.

(A) Of late the fulmination has been attributed to a nitrous ſulphur, generated in the precipitation, and adhering to the calx. The wonderful fulminating property of this calx is ſuppoſed to be ſufficiently accounted for by the detonation of nitre; but the preſence of it in aurum fulminans has hitherto been ſought after in vain. As vitriolic ſulphur may be diſſolved in a cauſtic lixivium, and precipitated by acids, it ſeems probable from analogy that the ſame property ſhould belong to nitrous ſulphur; but upon boiling in a cauſtic lixivium (§ VII.) the fulminating power is found entire, and, upon the addition of acids to the lixivium, no particular ſmell is obſerved, and the gold is precipitated, but in exceeding ſmall quantity.

(B) I have alſo employed vitriolic ether, that moſt powerful menſtruum of all inflammable bodies; this, on digeſtion for ſome days, begins to be tinged yellow, a golden pellicle appears upon the ſurface of the liquor, nay, a few grains of the calx lying at the bottom exhibit the ſplendor of gold: upon evaporation to dryneſs this ſolution yields ſplendid gold, not at all fulminating.

Gold ſeparated by ether from aqua regia, deſtitute of volatile alkali, when precipitated by by volatile alkali fulminates; but is totally void of that property, when thrown down by fixed alkali.

(c) Common ſulphur is not ſoluble in ſpirit of wine, unleſs when both theſe ſubſtances meet in the form of vapour; but we could not thence venture to conclude the ſame of nitrous ſulphur: I therefore digeſted aurum fulminans for eight days in rectified ſpirit of wine, but neither was the liquor tinged, nor did any thing remain on evaporation, nor was the calx found to be changed.

It is worthy of obſervation, that the non-fulminating calx of gold, upon digeſtion for a few days in rectified ſpirit of wine, grows black, and acquires a fulminating property, but weak, and ſcarcely ſimultaneous.

§ XIII. *Whether the Fulmination be occaſioned by Aerial Acid.*

That ſubſtance which enters into the compoſition of certain bodies, which, though very much reſembling air, is ſubſtantially different from it, has been called by modern writers fixed air, although it really is a true and diſtinct acid: ſome contend that this forms the bond of union between the particles of bodies, and in that ſtate is fixed, and deprived of its elaſticity; and that when a conſiderable quantity of this recovers its elaſticity at once, it muſt ſtrike violently

upon

upon the atmoſpheric air, thereby exciting undulations, and conſequently a ſound, which is various according to circumſtances.

They think, that in the preſent caſe the gold in ſolution loſes its fixed air, which it again recovers in ſtill greater quantity during the precipitation, as the calx is found encreaſed in weight;—the precipitate being then expoſed to fire, this aerial matter is ſuddenly forced to quit the calx, notwithſtanding the weight of the particles of gold; by means of which, however, the eruption being impeded, is made far more violent; hence the extraordinary noiſe.—The following obſervations will ſhew clearly that in this inſtance the fixed air does not act in this caſe.

(A) The elaſtic fluid which may be collected during the fulmination, is not abſorbed by water, nor does it precipitate lime from that fluid (§ III. c).

(B) Gold precipitated by mild fixed alkali, does not fulminate, unleſs the menſtruum contains volatile alkali.

(C) Gold precipitated by cauſtic as well as mild volatile alkali, fulminates.

(D) Gold in its precipitation rejects the aerial acid.

§ XIV. *The Phænomenon of Fulmination explained.*

From what has been ſaid it is plain that the vitriolic and marine acids are no leſs favourable

vourable to fulmination than the nitrous (§ IX.) yet that neither of theſe is otherwiſe neceſſary than as diſſolving and attenuating the metal (§ XI.); and finally, that no fulmination takes place without volatile alkali (§ XI.): the queſtion therefore is, how the volatile alkali acts in this caſe? To this queſtion I ſhall endeavour to give the beſt anſwer which experience has pointed out.

(A) From the very nature of the thing it is plain that ſo great a report, and ſo violent an exploſion, could not happen but by means of the copious and inſtantaneous eruption of ſome elaſtic fluid violently ſtriking the common air; and that this is the caſe in the fulmination we have already obſerved (§ III. G); but, for the better underſtanding this operation, it is neceſſary to conſider the conſtituent parts of aurum fulminans, namely, the volatile alkali and the calx of gold.

(B) It cannot be doubted that volatile alkali always contains phlogiſton: to paſs over other proofs, it may be ſufficient to mention its detonation with nitre. Now this phlogiſton may be ſeparated by means of a ſuperior attraction; ſo that the volatile alkali is decompoſed, and the reſiduum diſſipated in the form of an elaſtic fluid altogether ſimilar to that which is extricated during the fulmination: the ſource then from whence the elaſtic fluid is derived is obvious; it remains

mains to examine the medium by which the volatile alkali is dephlogiſticated.

(c) In thoſe metals which are called perfect, ſo great is the firmneſs of texture, and ſo cloſe the connection of the earthy principle with the phlogiſton, that by means of fire alone theſe principles cannot be diſunited; but when diſſolved by acid menſtrua, they muſt neceſſarily loſe a portion of their phlogiſton, and therefore, when afterwards precipitated by alkalis, which cannot ſupply the loſs, they fall down in a calcined ſtate: they however attract phlogiſton ſo forcibly that they can be again reduced to a metallic ſtate without additament, merely by an intenſe heat penetrating the veſſels. Gold therefore is calcined by ſolution; and this may be laid down as a fundamental poſition, being expreſly treated of, and, if I miſtake not, undeniably demonſtrated, in another place.

(D) Let the powder, now conſiſting of calx of gold and volatile alkali intimately united, be expoſed to an heat gradually increaſing, and let us examine what will be the conſequence:—the calx, which is united with the volatile alkali, by the aſſiſtance of a gentle heat ſeizes its phlogiſton, and when this is taken away the reſiduum of the ſalt is inſtantaneouſly expanded into the form of an elaſtic fluid, which is performed with ſo much violence, that the air muſt yield a very acute ſound. The calx may indeed be re-

 duced

duced by means of a very intenſe heat alone; in which proceſs the heat is decompoſed, and yields its phlogiſton to the calx, upon which the other principle, the pure air, is ſet at liberty. But in the preſent inſtance a ſmaller degree of heat ſeems to be neceſſary than when the volatile alkali is abſent; hence we may impute the reduction chiefly to it, although it can ſcarcely be denied that ſome particles are reduced by the heat alone. This we collect from the obſcure flaſh; for light, ſo far as experiment has yet ſhewn, is nothing more than the matter of heat, with a ſuperabundance of phlogiſton: a part therefore of the calx being reduced by the phlogiſton of the heat, the pure air (the other ingredient) is ſet at liberty, and attacks the ſuperfluous volatile alkali (which is now hot) and is ſo loaded with the phlogiſton of the alkali that it exhibits the appearance of light: for this cannot be attributed to the ſurrounding air, as the phænomenon takes place even in aerial acid. But that the volatile alkali can in this way produce a flaſh, is evidently ſhewn by another experiment: for if this ſalt be thrown into an hot crucible, it inſtantly exhibits a flaſh.—The volatile alkali, in its ordinary temperature, does not yield its phlogiſton to pure air; but that principle, being of itſelf very fugitive, upon the acceſs of heat is much more eaſily ſet at liberty, and unites with the pure air.

A ſingle

A ſingle cubic inch of gun-powder generates about 244 of elaſtic fluid, but the ſame quantity of aurum fulminans yields at leaſt four times as much; and hence we may eaſily underſtand the difference in their exploſive force.

The above explanation of the report, founded upon the knowledge of the compoſition of heat, and of aurum fulminans, ſeems abundantly ſatisfactory, but ſome phænomena ſtill remain not ſufficiently accounted for.

That careful calcination ſhould deſtroy the fulminating property, is not to be wondered at (§ IV. A), as the volatile alkali is the indiſpenſable material cauſe (§ XI.); but the peculiar alacrity which it acquires before the exploſive force is totally extinguiſhed, depends upon the nature of the materials, and of the operation. Thus the heat, when inferior to that neceſſary for fulmination, acts upon both the principles of the aurum fulminans, it prepares the metallic calx for a more violent attraction for phlogiſton; it alſo acts upon the phlogiſton of the volatile alkali, and looſens its connection: theſe two circumſtances muſt tend to the union producing the exploſion. But this effect has a maximum, and at this period the ſlighteſt friction ſupplies the defect of neceſſary heat, and produces the fulmination. The calcined gold alſo ſeems to collect and fix the matter of heat, though ſtill inſufficient, by means of its phlogiſton, in a certain degree; ſo that, by means of friction, though but very ſlight, it becomes capable of exerting its force: but when the heating is often repeated without producing its effect, the volatile alkali is by degrees diſſipated, and at length ſo much diminiſhed that the calx becomes inert. That this diſſipation is promoted by enlarging the ſurface is evident, and this explains the mode of action of the heterogeneous particles interpoſed between thoſe of the calx (§ IV. B).

But if aurum fulminans is capable of producing ſuch a prodigious quantity of elaſtic fluid, how does it happen that it remains mute and inert when reduced in cloſe veſſels? This I take to be the reaſon—every elaſtic fluid in the act of breaking forth requires a ſpace to expand in; if this be wanting it remains fixed, as has been already demonſtrated: taking this for granted, a calx of gold cannot be reduced in cloſe veſſels either by heat or by the phlogiſton of volatile alkali; for in either caſe it muſt evolve its elaſtic fluid, which by ſuppoſition it cannot do. Nothing remains to ſolve this difficulty but the ignition of the ſurrounding metal, by means of which the calx, in virtue of its ſuperior attraction, ſeizes the phlogiſton of the metal, which that ſubſtance, here as well as in other inſtances, is capable of loſing without the eruption or abſorption of any fluid whatever.

Whether

Whether this explanation be ſatisfactory or not I leave to the deciſion of the judicious.

(E) The ſtories told us by authors of the fulminating property of certain metals, particularly copper and ſilver, have not, I confeſs, been verified by my experiments; ſo they have either been ſilent upon ſome circumſtances neceſſary in the operation, or perhaps have been deceived by the detonation of nitrum flammans, or ſome other accidental occurrence. It is not ſufficient for the volatile alkali to adhere to the precipitate; for platina thrown down by this alkali retains a portion of the alkali very obſtinately, but yet does not fulminate on expoſure to fire. Beſides the preſence of volatile alkali, it ſeems to be neceſſary that the metallic calx ſhould be reducible by a gentle heat, in order to decompoſe it: but every exploſion is not to be derived from the ſame cauſes; nay, in this reſpect aurum fulminans, gun-powder, and pulvis fulminans, differ very much, though they agree in ſeveral particulars.

DISSERTATION XVIII.

OF

PLATINA.

§ 1. *Introduction.*

D. SCHEFFER was the firſt who properly examined the new metal which was lately found in America, and brought to us under the name of platina. In the year 1752 he inveſtigated its properties, and demonſtrated that in perfection it approached to gold, and therefore gave it the name of white gold: after him many experienced chemiſts, with laudable induſtry, have laboured in the accurate examination of this ſubſtance; ſo that we may ſay with juſtice, that there are few of the metals, though known and uſed for eighteen centuries and upwards, which have undergone ſo accurate an inveſtigation, by means of the moſt

moſt acute experiments; notwithſtanding this, however, many circumſtances occur to an enquirer which are ſtill obſcure, and not ſufficiently elucidated by experiment, and hence have ariſen many diſſenſions. Some of theſe points I hope I ſhall be able to elucidate, eſpecially as I am in poſſeſſion of a ſufficient quantity of platina, by the generoſity of the Baron Claudius Alſtromer, who had brought it with him upon his return from Spain.

§ II. *Platina precipitated by Means of vegetable Alkali.*

This new metal, diſſolved in aqua regia, exhibits, upon precipitation, many peculiar properties worthy of accurate examination. —We ſhall begin by the precipitate occaſioned by vegetable alkali.

(A) Aqua regis, compoſed of nitrous and marine acid, attacks platina, exhibiting a ſolution at firſt yellow, but which when further loaded grows red, and the colour grows the deeper as the ſolution is more loaded with the metal. Upon evaporation cryſtals are produced, of a deep red colour, frequently opake, but ſometimes pellucid, in general very ſmall, irregular, and reſembling angular grains, the real form of which I have not yet been able to diſcover.

(B) Theſe cryſtals, waſhed and well dried, require far more water than gypſum does to diſſolve them by boiling. The ſolution is yellow, and ſeparates ſome pale flocculi, which are probably martial: vegetable alkali does not diſturb the ſolution, nay, the cauſtic lixivium of this alkali, when hot, does not diſſolve the cryſtals, or at leaſt attacks them very faintly, even although a digeſting heat be applied, and the liquor evaporated to dryneſs. By this method the colour of the cryſtals is a little weakened, the aerated mineral alkali diſſolved in water takes them up and grows yellow, yet it remains clear, and in many hours does not depoſit any thing, but by evaporating to dryneſs it decompoſes them.

(C) The ſolution (A) upon the addition of a little vegetable alkali, either aerated or cauſtic, immediately, or at leaſt in a few minutes, depoſits ſmall ponderous red cryſtals, of a different nature from thoſe mentioned in B; theſe are ſometimes diſtinctly octaedral, and ſoluble in water; they are decompoſed with difficulty by the mineral, but are not changed by the vegetable alkali.

But if the alkaline ſalt be added in larger quantity, the ſuperfluous acid being ſaturated, there is ſeparated a yellow ſpongy powder inſoluble in water, which exhibits a calx of platina.

The clear ſolution (A) reduced ſo far by evaporation, that the remaining liquor conſiſted only of a few drops, upon the addition of the alkali exhibited the ſame phænomena

nomena as mentioned above, except that the cryſtalline powder was of a deeper yellow.

(D) Inſtead of the vegetable alkali, let the ſame, ſaturated with an acid, either vitriolic, nitrous, marine, or acetous, be employed; nevertheleſs, the red cryſtalline molecules appear; but by this method the whole of the platina cannot be ſeparated, as in the foregoing paragraph (C); for the ſolution retains a deep yellow colour, however abundantly theſe ſalts be added, nor does any genuine calx of platina fall, except upon the addition of an alkali; for which purpoſe either the mineral or vegetable will ſerve.

(E) I took the ſame weight of platina as in A, and tried it with an equal bulk of menſtruum, conſiſting wholly of nitrous acid; to which was added of common ſalt four times the weight of the metal: this nitrous acid was taken out of the ſame bottle as in A; in a digeſting heat all the platina was diſſolved; the ſolution was red, but more dilute than that in A; a yellow powder floated on the ſurface, but at the bottom a larger quantity of the ſame was found.

The clear ſolution, upon the addition of the ſmalleſt quantity of vegetable alkali, depoſited a copious yellow powder, which yet was ſoluble in a ſufficient quantity of water. The neutral ſalts, with a vegetable alkaline baſe, alſo precipitated a ſimilar powder more

ſlowly

ſlowly and more cryſtalline; but the mineral alkali, though employed in fifty times the quantity of the vegetable alkali, does not at all diſturb the ſolution, the abundant acid not being yet ſaturated.

The powder collected at the bottom was totally ſoluble in water, and in its properties agrees with the cryſtalline powder ſpontaneouſly ſeparated in B, but is of a yellow colour.

(F) I repeated the experiment with the ſame quantities, but inſtead of the nitrous acid and ſea-ſalt, I uſed the marine acid and nitre, well depurated. In this experiment the platina yielded a ſolution of a golden colour, together with a greeniſh powder, moſtly granulated, the more ſubtile part of which floated on the ſurface.

The clear ſolution did not depoſit any thing upon the addition of vegetable alkali, until all the ſuperfluous acid was ſaturated, but then yielded a metallic calx inſoluble in water.

The green powder is wholly ſoluble in a ſufficient quantity of water, and agrees, as to its properties, with the cryſtalline powder occaſioned by the vegetable alkali in C and D.

(G) Platina precipitated from aqua regia by a ſufficient quantity of mineral alkali, well waſhed, and diſſolved in marine acid, upon the addition of vegetable alkali immediately lets fall a cryſtalline powder; which

is

is alſo the caſe with nitre and other neutral ſalts, whoſe baſis is the vegetable alkali. I employed the additaments, eſpecially the neutral, dry, or at leaſt well ſaturated ſolutions.

(H) The caſe is the ſame with calx of platina diſſolved in vitriolic acid.

(I) The precipitate of platina is taken up alſo in the ſame way by nitrous acid freed from all admixture of the marine; but this nitrous ſolution exhibits different properties with the vegetable alkali from thoſe of the muriatic ſolution in G; for I could not obtain a diſtinct ſaline precipitate, without the addition of marine acid.

(K) That which I have now affirmed of the calx of platina, is alſo true of the precipitate occaſioned by vegetable alkali, after the depoſition of the ſaline powder (C).

(L) Upon comparing theſe experiments it will readily appear, 1ſt, That the precipitate which is firſt thrown down, on the addition of vegetable alkali to ſolutions of platina, is a ſaline ſubſtance, and different from the calx of this metal (C): 2d, That this ſaline precipitate is compoſed of calcined platina, marine acid, and vegetable alkali (D E F G and I): 3d, That by means of vitriolic acid a precipitate analogous to this may be obtained, compoſed of calcined platina and vegetable alkali, joined to vitriolic acid (H): 4th, That the whole ſolution of platina cannot be precipitated in the form

of

of a triple ſalt by the vegetable alkali, either diſengaged, or otherwiſe; but that a determined limit takes place, upon paſſing which it yields a metallic calx in the uſual way, like other metals.

§ III. *Platina precipitated by Means of the Mineral Alkali.*

The moſt celebrated chemiſt of the age, Mr. Margraaf, denies that a ſolution of platina can be precipitated by mineral alkali, which Dr. Lewis confirms on repeating the experiment. Now, as none of the metals adhere to acids with ſo much force as to refuſe quitting them on the addition of mineral alkali, platina would form a very ſingular exception; I therefore thought this circumſtance worthy of particular examination.

(A) I tried the common ſolution of platina with a ſolution of mineral alkali; each drop, on falling in, excited a violent effervеſcence, but no precipitate appeared. I ſtill continued, however, to drop in the alkali, and at length the ſolution began to grow turbid, and a ſpongy yellow powder was precipitated, conſiſting of a genuine calx of platina.

I afterwards effected the ſame more quickly, by employing the mineral alkali dry, and ſpontaneouſly calcined.

(B) In

(B) In order the better to determine the different efficacies of the fixed alkalis, I divided a ſolution of platina, as yet very acid, into two equal parts; to one of them I added ſmall portions of the vegetable, and to the other an equal weight of pieces of mineral alkali: between the addition of every two pieces I waited five minutes, till the efferveſcence had ceaſed. After the third addition, I obſerved ſmall cryſtals appearing in the firſt, partly on the ſurface, partly on the bottom; while at the ſame time no ſeparation of calcined platina appeared in the latter, until after the addition of fifty-ſix times the quantity of the vegetable alkali; the difference was, however, ſtill greater than at firſt appears from this experiment; for the vegetable alkali was cryſtallized, and therefore charged with the water neceſſary to its cryſtalline form; whereas the mineral alkali was ſpontaneouſly calcined; and although in equal weights of theſe two alkalis, the pure alkaline parts are as 3 to 2, yet 3 parts of vegetable alkali ſaturated only 1,71 of this aqua regia, while 2 of the mineral alkali took up about 2,6.

A difference ſo great as this, together with the then undiſcovered ſaline nature of the precipitate firſt thrown down by the vegetable alkali, undoubtedly contributed to deceive theſe experienced and deſervedly admired chemiſts; a circumſtance which is by no means wonderful.

(C) In

(c) In reſpect of precipitation, therefore, the mineral alkali ſuffers no impeachment, but rather the vegetable exhibits a very ſingular habitude with regard to diſſolved platina, which it does not poſſeſs with any other metal.

§ IV. *Platina precipitated by Means of volatile Alkali.*

Dr. Lewis was the firſt who ſhewed that platina may be precipitated by ſal ammoniac; this is a ſingular phænomenon, which we ſhould by no means expect from a neutral ſalt, and which I have never yet ſeen explained.—The following obſervations are intended to illuſtrate this proceſs.

(A) The volatile alkali, whether mild or cauſtic, precipitates platina in the ſame way as deſcribed § II. C; at firſt it throws down the metal in a ſaline form; and, although the grains be ſmall, yet they are of a cryſtalline ſhape; which upon examination is ſometimes found to be diſtinctly octaedral.

Their colour varies according to the intenſity of the ſolution; when red, it depoſits red cryſtals; and when more dilute, no other than yellow. After the ſuperabundant acid has been ſaturated, the ſame alkali precipitates the platina truly calcined.

(B) The ſaline precipitate, though ſlowly taken up by water, yet if the quantity of water

water be ſufficient is totally diſſolved, and may by evaporation be reduced to more regular cryſtals.

The mineral alkali diſſolves theſe cryſtals; but ſcarcely any ſigns of decompoſition appear, unleſs the yellow ſolution, evaporated to dryneſs, be again diſſolved in water; for then the metallic calx reſts at the bottom, and the ſolution wants the yellow colour. The vegetable alkali has ſcarcely any effect in this way, for after repeated exſiccation, the ſolution remains clear and yellow; but here it appears very probable, that this alkali takes the place of the volatile, for in larger quantities, and eſpecially when the cauſtic vegetable alkali is employed, the expulſion of the volatile alkali is in ſome degree manifeſt by the ſmell.

(C) The volatile alkali, ſaturated with any acid, throws down a ſimilar ſaline precipitate, at leaſt it produces the effect, whether it be joined with vitriolic, nitrous, or marine acids; but theſe neutral ſalts precipitate only a determined quantity of platina; for, after the ceſſation of their effect, the remaining liquor, upon the addition of vegetable or volatile alkali, lets fall a pure calx.

(D) The calx of platina, precipitated by mineral alkali, and then diſſolved in any ſimple acid, as vitriolic, nitrous, or marine, exhibits nearly the ſame phænomena with volatile alkali, whether diſengaged or otherwiſe, as it does with the vegetable alkali.

(E) Upon conſidering theſe experiments, therefore, we may conclude, that platina, diſſolved in acids, forms at firſt, as well with the volatile as with the vegetable alkali, a triple ſalt, which is difficultly ſoluble, and therefore almoſt always falls in the manner of a precipitate, unleſs the quantity of water be more abundant than ordinary.

§ V. *Platina precipitated by Means of Lime.*

(A) Lime, whether aerated or cauſtic, precipitates platina in the ſame manner as the mineral alkali does, without any cryſtalline appearance.

(B) Upon the conſideration of theſe phænomena, there appears a ſingular analogy between the vegetable and volatile alkalis, and between the mineral alkali and lime. A like agreement takes place between theſe ſubſtances in other inſtances. I ſhall mention one remarkable example :—alum, extracted from argillaceous matters, by means of vitriolic acid, ſometimes cannot, without difficulty, be reduced to ſolid regular cryſtals ; but by the addition of a ſmall quantity of vegetable alkali this inconvenience may be remedied, and the volatile alkali produces the ſame effect. It may be ſuſpected, that this is owing to the abſtraction of ſuperabundant acid; but it cannot be done either by mineral alkali or lime, both of which are capable of ſaturating the acid; beſides, not only the vegetable and volatile alkalis aſſiſt the cryſtallization of alum when they are diſengaged, but alſo when united with acid, which makes the reſemblance complete. The matrixes of alum frequently contain the proper alkali, either naturally combined with them, or ſuperadded in the roaſting; and hence it is ſeldom neceſſary, in the preparation of alum, to promote the cryſtallization by alkalis.

§ VI. *Difficulty with which Platina is fuſed.*

It is well eſtabliſhed, that of all known metals platina is the moſt difficult of fuſion; for, in its perfect ſtate, it is ſcarcely to be overcome, except in the focus of a burning mirror; while mercury, on the contrary, finds ſufficient heat in the coldeſt winter to preſerve a fluid form; but not long ſince, the celebrated Deliſle diſcovered a method by which platina may be fuſed even by a common fire. Thus the precipitate obtained by ſal ammoniac, expoſed without additament to a moſt violent degree of heat in a blaſt-furnace, yields a poliſhed metallic globule, which is ſometimes ſufficiently malleable. I have repeated the experiment with ſucceſs; but in order to obtain the regulus in a malleable ſtate, the quantity muſt be very ſmall, and the heat very intenſe.

(A) I tried whether platina, precipitated by ſal ammoniac, could be fuſed by the blow-pipe. In order to make a ſmall portion remain on the charcoal, notwithſtanding a violent blaſt, I added to it a little microcoſmic ſalt in fuſion, and in a few minutes obtained a poliſhed globule, but ſo very ſmall, that when beaten out it yielded a circular plate of only one line in diameter. I found means, by the addition of microcoſmic ſalt, to reduce ſeven or eight of theſe planes into one maſs, equal in bulk to the head of a common pin; and after beating this out, I once reduced it again to a globular form, ſtill preſerving its malleability, but could not fuſe it again; for, being imperfectly fuſed, it broke under the hammer.

Borax is ſcarcely of any uſe in this operation, for it expands upon the coal together with the precipitate.

(B) The ſaline precipitate thrown down by volatile alkali, treated in the ſame manner, exhibits the ſame properties as the foregoing.

(C) I found ſo great reſemblance between the precipitate occaſioned by the volatile and by the vegetable alkali, that I ſhould have concluded, that in this experiment they would prove to be ſimilar; but I have often had occaſion to ſee how little analogy is to be confided in; I therefore made the experiment with the cryſtals obtained by vegetable alkali, and found my conjecture to be juſt.

(D) The cryſtals obtained by ſpontaneous evaporation (§ II. B) after completely drying, when added to the microcoſmic ſalt in fuſion, decrepitate more violently than thoſe obtained by means of the alkaline ſalt (§ II. C; and IV. A). Somewhat, however, remains in the fixed maſs, which is not unfrequently reduced upon its ſurface, yielding a pellicle of a ſilver colour; but I have not hitherto been able to reduce it to a globule. Thus far I have advanced, namely, to obtain the platina collected together within the ſalt, in a white maſs of an irregular form; but the particles of this ſpongy maſs were ſeparable by mechanical force. This is the caſe with the calxes of platina, by whatever alkali they are precipitated (§ III. A; II. C; and IV. A); therefore it ſeems very probable, that the principle which diſpoſes to fuſion is ſupplied by the vegetable, and alſo by the volatile alkali.

§ VII. *Properties of depurated Platina.*

By the method now deſcribed, I obtained ſeveral very beautiful pieces of regulus; they were, it is true, exceeding ſmall, but wonderfully malleable; and were freed from iron by repeated fuſion with microcoſmic

 ſalt,

ſalt, more completely than by any other method hitherto known. It is proper to obſerve, that the crude platina was ſelected, and repeatedly boiled in marine acid, until the menſtruum could not extract any more iron. By this proceſs 0,05 were ſeparated, the remaining part of the iron being doubtleſs ſo enveloped by the particles of platina that the boiling acid cannot have acceſs to them. This platina, after waſhing, was diſſolved in aqua regia freed from all iron, and then precipitated by the pureſt ſal ammoniac. I ſhall therefore deſcribe the qualities of the regulus obtained from this precipitate.

(A) Its colour is that of the pureſt ſilver.

(B) The very ſmall globules are wonderfully malleable, but when many of theſe are collected together they can ſcarcely be ſo perfectly fuſed as to preſerve the ſame degree of malleability.

(C) A magnet, though of great power, does not act upon them in the leaſt, nor is the moſt delicate magnetic needle affected by them.

(D) They cannot be diſſolved by any ſimple menſtruum, except the dephlogiſticated marine acid.

(E) Aqua regia, compoſed of the acids mixed, diſſolves them, is yellow at firſt, and, when more ſaturated, red; on evaporation the ſolution yields ſhapeleſs cryſtalline grains, though I muſt confeſs, that in the

place

place of theſe I have ſometimes obtained nothing more than a ſaline maſs.

(F) Their habits with alkalis, whether diſengaged or ſaturated with acids, are the ſame as above deſcribed.

(G) The phlogiſticated alkali, well ſaturated, and freed from the ſmall portion of Pruſſian blue which it diſſolves, occaſions no precipitation, but the colour of the ſolution is rendered darker. This lixivium therefore diſſolves platina, as well as ſome other metals. Not the ſmalleſt veſtige of Pruſſian blue appears, which yet is evidently ſeen upon the addition of a portion of martial vitriol, amounting to only 0,001 of the platina contained in the ſolution, although 0,001 of martial vitriol contains only 0,00023 of iron.

§ VIII. *Whether Platina be a Metal diſtinct from all others.*

Although many of the moderns give platina a place among the metals, yet there are ſome naturaliſts of high reputation who conſider it as nothing more than a mixture of gold and iron. We ſhall not here conſider the arguments on both ſides, but reſt entirely upon the concluſions which follow clearly from the preceding experiments.

(A) As to iron, there is no doubt of its preſence in platina, as is evidently ſhewn both by the magnet and the phlogiſticated lixivium: but whoever examines the metals accurately will find that they never occur in a perfectly pure ſtate. Gold is contaminated more or leſs with ſilver, copper, or iron; ſilver with copper and arſenic; copper with iron, and that generally in ſuch a quantity as to be diſcernible, but ſometimes in ſuch ſmall portions as to be concealed; nickel contains cobalt; and ſo on. Let us now ſuppoſe that native platina is never found without iron; yet it does not follow from thence that iron enters into it as one of its conſtituent principles.

(B) This iron may be artificially ſeparated, or at leaſt ſo much diminiſhed as not to be in the ſmalleſt degree ſenſible, either to the magnet or the phlogiſticated lixivium (§ VII.) With what appearance of probability then can it be ſaid, that in depurated platina (which in 100,000 parts is ſuppoſed to contain 99,977 of gold) the nature and diſtinguiſhing properties can be ſo changeable as that a ſmaller quantity than 0,00023 of iron (§ VII. G.) ſhall operate ſo as to conceal the properties of both the ingredients?

(C) I have long wiſhed to get a piece of platina entirely crude, and unchanged by art; for not only is iron ſuppoſed to be a principle of this metal, but it is aſſerted to be magnetic: it is known that grains of platina are found mixed with gold in the bowels of the earth, and that the gold is freed from

from them in iron mills by means of mercury; may not the magnetiſm therefore be occaſioned by the iron which adheres during this operation, as we know that iron receives that property by percuſſion and other means? — beſides, a ſuitable ſituation, long continued, alſo generates that quantity; and perhaps to this cauſe may the magnetiſm be owing, if it actually does take place in crude platina; if not, it muſt be entirely attributed to art.

In the year 1774 two Spaniards who had come to Upſal, from America, preſented me with two ſorts of platina, one of which had been waſhed with mercury, in order to ſeparate the gold; the other rude, which they aſſerted had never been expoſed to amalgamation. This latter was to me a very acceptable preſent; but my pleaſure ſoon vaniſhed, for a few ounces of it, expoſed to fire in a glaſs cucurbit, ſent forth mercurial vapours, which formed into globules on the neck of the veſſel. As platina is mixed with particles of gold, there is very little probability that it ever comes to Europe pure: it may happen alſo that it repeatedly undergoes that operation, for even ſuch as is brought to Europe yields grains of gold: when once deprived of the gold it is thrown out; and this it moſt probably is which, after a ſeries of years, is conſidered as pure.

DISSERTATION XIX.

OF THE

WHITE ORES OF IRON.

§ 1. *An accurate Knowledge of Ores necessary to the proper Treatment of them.*

OUR omnipotent Creator has provided for the ufe of man an inexhauftible ftore of natural bodies, which are to be found in the external covering of the globe; fome of thefe we have accidentally learned to employ to our advantage, others we have been urged by neceffity to feek; and by flow degrees, and after many trials, we have difcovered the proper treatment of them: but the greateft number we ftill neglect as ufelefs, being ignorant of their value.

It

It is obvious, that in proportion as men become more perfectly acquainted with the virtues, qualities, and compoſition of bodies, the more perfectly and eaſily will they be able to apply them to their advantage and convenience. Upon that particular, therefore, ſhould our chief care be employed, for a proper acquaintance with the ſtores of nature will certainly be followed by the application of them to uſe: nevertheleſs, ſo provident has nature been againſt human ignorance and ſloth, that the rudeſt labour is not without ſignal advantage: thus in the darker ages we find the richeſt minerals uſed as tributes, a circumſtance which naturally followed the diſcovery of them; yet they were not valued in proportion to their goodneſs. When, by the experience of ages, the various qualities of theſe bodies were diſcovered, the foundation of metallurgy began to be laid; and in proportion as the ſuperior ſkill of men now enables them to obtain more metal from poorer veins, nature ſeems to have diminiſhed the former ſuperabundance of theſe productions. The chemical knowledge of the preſent times would be too much enriched, if the former abundance ſubſiſted; and on the other hand, the rude and unſkilful attempts of the firſt inventors would be entirely uſeleſs, had they been cramped by the ſcarcity which is now found to take place.

§ 11. *Phy-*

§ II. *Phyſical Qualities of the white Ores of Iron.*

Theſe ores have received divers denominations, from the ſingular heat with which they are accompanied. In Germany they are called *ſtahlſtein* or *ſtahlertz* (as the iron got from them could be changed into excellent ſteel) as alſo *weiſſe, eiſenſpat, pflintz*, and other names: in France they are called *mines de fer ſpatique*, although it muſt be confeſſed that they are not always ſpathous; and that moreover many which are of a ſpathous texture, and loaded with iron, do not belong to this claſs.

(A) The texture of theſe minerals is almoſt the ſame as that of the calcareous ſtone, yet it is rarely found compact, and compoſed of impalpable particles; it is ſometimes ſquamous, ſometimes granulated with ſmall diſtinct particles, ſome of them ſhining, but in general it is ſpathous. We do not ſpeak of them here in their complete and perfect ſtate; for the figure of their parts is more or leſs deſtroyed by ſpontaneous calcination, nay, the whole maſs is at length reſolved into a powder: ſometimes it is found ſtalactitic, fiſtulous, and ramous, or even cellular, nay ſometimes germinating like moſs.

(B) They are ſometimes, but very ſeldom, ſo hard as to ſtrike fire with ſteel; but though

though (when found mixed with flint, and newly dug up) they are of this kind, yet they ſoon loſe that property: in other reſpects, when perfect, they generally reſemble calcareous ſtone, unleſs when expoſed to the air for ſome time, by which the union of their parts is gradually diminiſhed.

(C) The colour is white, but the ſurface which comes in contact with the air grows gradually brown, or even blackiſh; yet ſo long as the iron, which is converted into an ochre, remains in them, they have a ferruginous hue; but though the ſurface is thus changed, the internal parts remain the ſame, and upon filing or breaking exhibit the natural colour.

This change is effected by the air, not upon the iron, as is commonly believed, but upon the white calx of the manganeſe, which is dephlogiſticated by the ſurrounding atmoſphere; a circumſtance which it is ſufficient here to mention, as it will be more accurately explained hereafter (§ VII. G).

(D) The ſpecific gravity of the ore, when perfect, varies between 3,640 and 3,810, and is diminiſhed according to the degree of calcination. That ore, whoſe particles ſcarcely cohere, but are quite ſeparated, is from 2,5 to 2,9; but that which is not perfectly corroded, from 3,3 to 3,6.

(E) The ore, whether perfect or calcined, is rarely attracted by the magnet, though the

the martial part ſometimes amounts to nearly half the weight.

§ III. *Situation of theſe Ores in Mountains.*

The white ores of iron are found, but very ſparingly, in Sweden: Suartberger, (*i. e.* Black Mountain) near Schiſshytta, in Dalekarlia, has its name from its ſurface; which is grown black by calcination. This mountain is high, and naked upon the ſummit, which is croſſed by a broad calcareous vein, with ſhining particles of ſpar, and a white ore of iron, together with galena, pſeudo galena, and black ore of iron, pyrites, ſchoerl, and garnet intermixed. In the old mines at Hællefors, or the eaſtern mines, the rock itſelf appears to conſiſt of a white ore of iron. It is ſometimes found alſo in other mountains, but generally either in ſmall quantity or very poor in metal.

Germany is rich in theſe ores: many mountains about Smalkald contain them: in that which is called Stahlberger a broad vein, almoſt horizontal, occurs from twenty-five to thirty fathom thick; this conſiſts of an irregular ſpar, in which are diſperſed quartz, and pieces of the ore, which are found of a better quality, in proportion as they are more deeply ſeated. The pendent ſide, which is uppermoſt, is compoſed of a ſandy ſtone from nine to twenty fathom high, but the lower, which is the foundation,

tion, is margaceous, and is found more indurated towards the lower parts, and at the very loweſt is extruded by a blue mica; the ſides ſcarcely cohere to the vein.

In Nauſſavia the whole mountain ſeems to conſiſt of a yellowiſh ore of iron, certain veins of which are accompanied with copper, others with hæmatites.

In Upper Stiria, at Eiſenarg, is ſituated Arzberg, in circuit 6,000 fathoms, in diameter 900, and in height 450: it is deſcribed by ſome as irregularly accumulated and concreted, and as conſiſting of maſſes of quartz, charged with argillaceous earth and white ore of iron; but others contend that the ore is there found not only in heaps but alſo in various veins.

France and Spain produce great quantities of theſe ores.

The examples above cited ſeem to indicate that the white ores of iron are found ſometimes in heaps, but that they alſo form ſometimes veins, ſometimes ſtrata, and ſometimes whole mountains. I have never found that they contained any organized bodies, a mark by which the moſt ancient productions of the earth have been diſtinguiſhed.

§ IV. *Properties of theſe Ores examined by the Blow-Pipe.*

Experiments, with this inſtrument, although made upon ſmall pieces, yet in general

neral ſhew the nature of the ſubſtance examined with conſiderable certainty, and point out the method of treatment proper for larger quantities; therefore it is that I am of opinion we ſhould begin our experiments in that way.

(A) The white ore of iron, expoſed to the flame, at firſt is apt to decrepitate, and that the more violently, as it is of a more cryſtalline texture; ſo that that which is of a denſe texture, and whoſe particles are ſcarcely diſcernible, decrepitates little or none: a certain degree of ſpontaneous calcination alſo overpowers this decrepitating quality.

Another, and a more remarkable effect of the fire, is a ſudden change of colour: the whiteneſs ſoon changes to a brown, which quickly gives place to a blackneſs, which cannot be diſcharged even by violent and long-continued heat.

A piece of the ore, when blackened by the fire, is always attracted by the magnet, although, as is frequently the caſe, it had not been obedient to it before.

But the ore alone is not fuſed without great difficulty, though the fire be violent and long continued. Upon fuſion it again eludes the force of the magnet.

(B) A ſmall portion, added to a globule of microcoſmic ſalt in fuſion, is diſſolved with more or leſs efferveſcence, and imparts an iron colour, that is, a greeniſh or a yellowiſh

lowiſh brown, which upon cooling grows weak, and at length entirely vaniſhes.

When the globule, after cooling, is again ſoftened, not by the interior and blue cone of flame, but by the exterior and leſs defined part, a red colour is generated, which alſo vaniſhes upon cooling; this is made more diſtinct by the addition of a ſmall piece of nitre, but upon cooling is weakened. Fuſion by the blue cone, continued for ſome time, extinguiſhes the redneſs, ſo that the iron tinge appears: in this way the red colour may be many times alternately diſcharged and renewed.

When the globule is ſuperſaturated with the ſalt, upon cooling it grows opake, white or black, according to the different quantities of the calx and the iron; and in the latter caſe it ſometimes poſſeſſes a metallic ſplendor.

A variety in the proportion of the principles occaſions great changes in the phænomena;—thus the original effervеſcence is both more viſible and more durable when the calx abounds. When the iron is deficient, its colour can ſometimes ſcarcely be diſcerned; and when the quantity of manganeſe is very ſmall, and that of iron large, the redneſs ſcarcely appears without the addition of the nitre.

(c) The white ore of iron is diſſolved in the ſame manner by borax, *viz.* the effer-

veſcence

vefcence is more or lefs confpicuous, according to the quantity of calx.

The vitreous globule frequently acquires an obfcure reddifh yellow colour, which yet, upon the continued application of the blue cone, is totally deftroyed, the martial tinge remaining: but by nitre, or by foftening alone, which is effected by the exterior cone, the hyacinthine colour above mentioned again appears.—Thefe changes may be produced at pleafure.

By fuperfaturation the globule becomes opake, black or white.

(D) The mineral alkali fufed in a filver fpoon takes up the ore with an effervefcence more or lefs remarkable, yet divides it but little, nor is the milky globule rendered brown, unlefs by a larger addition, and a longer continued fire, and then it grows black.

(E) Thefe experiments fhew that the ore contains lime fomewhat filiceous, iron, and manganefe; and although thefe ores may appear to many of little confequence, yet they have difcovered to me a new metal, which by other means could not be difcovered. The properties of manganefe, hereafter explained (§ VII.) will illuftrate this affertion more fully.

§ V. *Pro-*

§ V. *Properties of theſe Ores examined by the Via Sicca.*

(A) 100 parts finely powdered, and expoſed upon a tile to the fire, grow quickly black, and become obedient to the magnet; in this experiment ſometimes red ſpots appear here and there, occaſioned by the admixture of pyrites. An heat of two or three hours occaſions a loſs of weight different according to the variety of the ore; the loſs is at the leaſt 15, and at the moſt 40 aſſay pounds: by a longer continuance of the heat the loſs is not increaſed, nor does the black colour diſappear, nor are any ſigns of fuſion to be obſerved.

On calcination, no ſmell is perceptible, unleſs there be an admixture of ſome pyritous particles.

When the pieces are ſufficiently roaſted, and after cooling put into water, they often generate heat, and form a ſort of lime-water.

(B) In order to learn the nature of the ſubſtance expelled by fire, 100 of the pulverized ore was put into a ſmall retort, to which was adapted a receiver, which by a lateral tube conducted the elaſtic fluid into a glaſs veſſel full of water, and inverted; the fire was then gradually increaſed, until the bottom of the retort began to grow ſoft; in the mean time a ſmall quantity of liquor

 was

was found in the retort, but in the inverted glaſs a large quantity of elaſtic fluid.

The liquor in the receiver was found of an aqueous nature, but for the moſt part ſo ſmall in bulk as ſcarcely to be collected, ſeldom ſo much as 0,1, and never exceeding 0,2. The ore, when perfect and cryſtallized, uſually yields a little more water than when broken down by ſpontaneous calcination, or when naturally denſer.

The elaſtic fluid, when confined by mercury, ſometimes occupied 30 cubic inches, but was generally leſs: on examining this it was found to be moſtly abſorbed by water, and to communicate to it a pungent acidulous taſte, together with the property of making the tincture of turnſole red. It precipitated lime-water, extinguiſhed flame, and deſtroyed animal life: theſe properties ſhew it to be the aerial acid; the portion which remains and refuſes to unite with water, is common air, which doubtleſs was at firſt contained in the retort. When the aerial acid is ſeparated by water, a ſpecies of deflagration takes place; yet it ſhould be obſerved that inflammable air is almoſt always abſent.

The black reſiduum in the retort, though it be not ignited, is ſometimes attracted by the magnet.

(c) This ore, pulverized and ſtrewn upon hot coals, exhibits a kind of phoſphoric appearance, which is light and momentary; but

but when expoſed to fire alone in a cloſe crucible, it quickly liquefies, and perforates the bottom. This effect is occaſioned by the calcareous earth in the ore diſſolving the ſiliceous and argillaceous earth of the veſſel: theſe three, when mixed, eaſily flow, and beſides, the calxes, both of iron and manganeſe, which are here preſent, promote the vitrification very much.

(D) The powder, let fall into nitre, fuſed and ignited, ſhews no diſtinct detonation, but a crackling is heard.

(E) I have attempted the reduction of theſe ores by many different ways, but it is only neceſſary to mention thoſe which are particularly uſeful in the extraction of iron.

The firſt, moſt ſimple, and in many caſes the beſt, is this : — the bottom of a crucible is covered, to the thickneſs of about half an inch, with powdered charcoal ; this powder is moiſtened with water, mixed with a ſmall portion of argillaceous earth, ſo that upon compreſſion the particles may the better adhere together, and to the crucible ; the ſides are lined in the ſame way, but thinly. The ſuperficies of the ſtratum ought to be rather concave, ſo as to receive in the lower part 100 of pulverized ore, covered with calcined borax ; for that which ſtill retains the water of cryſtallization upon boiling, diſperſes many particles of the ore ; finally, another crucible is to be in-

 verted,

verted, and luted on, and the whole expofed to a proper fire.

The fecond method is this:—100 of the ore, mixed with an equal weight of mineral fluor, and half of apyrous clay, is put into a crucible, prepared after the manner above defcribed, and treated in the fame way, but without the addition of borax.

The third is directed by D. Scheffer:—to 1 part of ore are added 1 of tartar, 1 of charcoal-duft, 1 of glafs, 1 of white, and 2 of black flux; the mixture is put into a crucible prepared without lining, and fhut as before.

The fourth, which has been long in ufe, is defcribed by Snack, and is preferred to all others by D. A. Swab, although it is very complex:—to 100 of the ore are added an equal weight, or 100 of fal ammoniac, 100 of tartar, 100 of glafs gall, 50 of borax, 50 of charcoal-duft, and of black flux 200; the mixture, put into an unprepared crucible, is covered with common falt, and, being covered, expofed to the fire.

In order to compare thefe different methods, with refpect to the white ore of iron, I treated different portions of it according to all the different methods, and that without previous calcination, which in this inftance is of no effect. That which I tried was a fpathous fruftum, not yet injured by calcination, brought from Eifenartz, in Upper Stiria:

	lb.
Of this 100, according to the firſt method, yielded of a regulus nearly of the ſplendor of ſilver - - - -	42
According to the ſecond, of a regulus of an aſh colour - - - -	39
By the third, a regulus of an aſh colour, but nearly cryſtallized on the ſurface - - - - -	$29\frac{1}{2}$
By the fourth, of a regulus almoſt white and ſplendid - - -	36

I found nearly the ſame progreſſion to hold with the ore of Naſſau, and with the other ores, examined in the ſame way: in general the weight of the regulus never attains to 50, but is often 30, 20, 10, nay even ſometimes no more than 2, though the ore has been made black by roaſting, and is attracted by the magnet; but hereafter it will be demonſtrated that the blackneſs by fire is not occaſioned by the iron, but by manganeſe. The pureſt calcareous ſtones are ſeldom entirely without iron. The cleareſt Iceland ſpar grows red by long calcination; and even by the humid way yields its metal to phlogiſticated alkali.

The ores which are ſo poor as not to yield a regulus without difficulty, are uſually brought to that ſtate by a ſmall quantity of white arſenic, or rather of litharge; for by this method the ſcoria is made thinner, and the ſmall globules permitted to ſubſide and collect.

§ VI. *Properties of theſe Ores, examined by the humid Way.*

(A) The white ores of iron effervеſce indeed with acids, but in general more weakly than the calcareous ſtones; and ſometimes no motion is obſerved, unleſs pulverization and heat be both employed. That calcareous earth is preſent will appear from what follows: but the reaſon why it only effervеſces ſlowly, is to be ſought partly in its proportion, and partly in its intimate connection with the other principles.

(B) All thoſe acids which are uſually called mineral diſſolve this ore, if it be well pulverized, and a due degree of heat applied. The ſolution made by vitriolic or marine acid is generally of a yellow green; that by the nitrous of a red or yellow brown; the marine acid diſſolves it ſooner than the reſt: theſe colours vary a little, in proportion to the quantity of metallic parts. Sometimes a brown redneſs at firſt appears, which then vaniſhes, but ſometimes perſiſts, unleſs ſugar, or ſome ſubſtance rich in phlogiſton, be added.

Almoſt always ſomewhat remains undiſſolved, which yet, upon examination, appears to be of a different nature. I have frequently ſeen grains of ſchoerl, zeolith, quartz, mica, nay fibres of aſbeſtos intermixed: but theſe are foreign matters, which,

which, although they ſometimes form above 0,2 of the maſs, yet are not a neceſſary component part of the ore.

The ſolution made by vitriolic acid, upon evaporation yields green martial cryſtals; and that made in marine acid, without heat, ſometimes by ſpontaneous evaporation concretes into ſpathaceous forms, compoſed of hollow pyramids.

(c) During the ſolution an elaſtic vapour eſcapes, which, when extricated by vitriolic or marine acid, is not inflammable, even although the crude ore be attracted by the magnet.

The quantity of water is eaſily diſcovered by performing the operation in a large bottle, cloſed ſo as to give exit to the elaſtic fluid, but not to the moiſture; for the diminution of weight in this caſe indicates only the volatile aerial fluid, whereas the loſs ſuffered during calcination ſhews the weight both of the elaſtic fluid and of the water.

(D) As the various qualities above mentioned indicate the preſence of lime, I attempted to ſeparate it in the following way:—let a portion of the pulverized and calcined ore weighed, be put into diluted nitrous acid, and let the mixture be ſhaken for a quarter of an hour; after which let the powder be collected on a filter, and the clear liquor precipitated with aerated fixed alkali: by this method a white ſediment was ob-

 tained,

tained, which upon examination ſhewed all the properties of lime. I employed the calcined mineral, and the nitrous acid, leſt any thing metallic ſhould be taken up during the ſhort agitation, otherwiſe the end might be anſwered by the marine acid; but then it is neceſſary, in evaporating the ſolution to dryneſs, to expoſe it to a more intenſe heat, that the diſſolved metal may be ſpoiled of its menſtruum, for the lime retains the menſtruum more obſtinately: hence, after this operation, the ſalited lime may be elixated from the reſiduum by water, and precipitated by an alkali.

The weight of lime varies much; in ſome ores I found a few hundredths; in the ſpathaceous kind about 0,1 conſiſts of lime, in others 0,5, but it is never entirely wanting.

(E) Into a ſolution of the ore made with the pureſt marine acid, I poured a few drops of ſolution of terra ponderoſa in the ſame menſtruum, but the tranſparency was not in the leaſt diſturbed; from whence I conclude, that there is no vitriolic acid preſent.

(F) The ſame is true of the marine acid; for I examined the ſmall portion of water expelled ſolely by heat in the diſtillation (§ V. B), and could not, even by paper tinged with turnſole, diſcover any traces of an acid: I alſo poured concentrated vitriolic acid upon the powdered ore in a retort, and into the receiver a ſmall quantity of diſtilled water,

water, as water very greedily attracts the marine acid in a ſtate of vapour; but neither by the ſmell, by any viſible vapour, nor by precipitants, could I diſcover the ſmalleſt ſigns of a mineral acid, unleſs the heat was increaſed to ſuch a degree as to force over ſome of the vitriolic acid. The water in the receiver was not at all diſturbed by ſolution of ſilver, although, upon touching it with the end of a glaſs rod wet with marine acid, the ſilver was immediately precipitated, and a white ſediment ſeparated.

I conclude therefore with reaſon, that the vitriolic and marine acids, if they ſometimes happen to be preſent, do not belong to the proper compoſition of the ore; and, in fact, how could the aerial acid exiſt together with theſe, being eaſily expelled by either of them?—and how could the marine acid, which with lime and iron forms deliquefcent ſalts, in this caſe form with them an ore which not only remains dry in the open air, but even undergoes ſpontaneous calcination?

§ VII. *Principal Properties of Manganeſe.*

I have hitherto frequently named manganeſe, and mentioned ſeveral circumſtances which cannot be properly underſtood without previouſly conſidering its nature. It is neceſſary therefore, before we proceed further, to deſcribe the principal properties of this

this ſubſtance, ſo far as they have hitherto been diſcovered.

(A) The mineral ſubſtance which is called black, or glaſs-makers, magneſia, is ſcarcely any thing more than the calx of a new metal.

It is many years ſince I began to ſuſpect that ſome metal, different from all thoſe formerly known, lay concealed in magneſium, being partly led to this opinion by the ſpecific gravity, partly by its property of tinging glaſs, and partly by its ſeparating from menſtrua on the addition of phlogiſticated alkali, a circumſtance which takes place with all the metals, but not with any earth. In the mean time I attempted the reduction of it in various ways, but in vain; for either the whole maſs ran into ſcoriæ, or I obtained only diſcrete ſphærical atoms, ſo much loaded with iron as to be magnetic. On account of its being ſo difficult of fuſion, I at firſt imagined it had ſome affinity with platina: at length Mr. Gahn, without knowing any thing of my experiments, ſucceeded in obtaining larger pieces of regulus by means of a moſt intenſe heat; and Mr. Scheele, in 1774, publiſhed ſeveral curious facts relating to mangaueſe.—The principal things reſulting from the experiments of theſe gentlemen, and from my own, ſhall be the ſubject of the following pages.

(B) The reduction is effected in the following way:—a certain quantity of manganese, formed with oil or water into a ball, is put into a crucible prepared with charcoal-duſt, as before deſcribed (§ V. E), the empty ſpace is then filled up with charcoal-duſt; another crucible is inverted by way of cover, and luted, and the whole apparatus expoſed to the moſt intenſe heat which the laboratory can produce, for an hour, or more if neceſſary. The veſſels being cooled and emptied, a regulus is formed, ſometimes conſiſting of many pieces, which, collected, in ſome caſes amount to 0,3 of the manganeſe.

If the fire be weaker than neceſſary, either no reduction takes place, or the metallic particles are diſcrete, not being ſo fuſed as to run properly together. If during the operation the crucible falls, ſo that the metal ſhall touch the naked ſide of the veſſel, vitrification is inevitable.

(C) The metal obtained, which I call manganeſe, is about the ſpecific gravity 6,850.

The ſurface is generally brown, and the larger pieces of regulus are ſcarce ever found globular, but knotty and irregular, which, no doubt, is owing to the difficulty of fuſion, in which it ſeems to exceed even forged iron.

Being harder than iron, it breaks under the hammer: the fracture is irregular and rough,

rough, with a ſort of whitiſh metallic ſplendor, which ſoon ſpontaneouſly grows brown: even the ſmaller pieces are not magnetic; but the powder is generally obedient to the magnet, though the admixture of iron be avoided with all poſſible care.

Some ſmall pieces, expoſed to the fire in an Heſſian crucible, in a blaſt-furnace, and kept there for twenty minutes, yielded a yellowiſh brown glaſs, and a ſmall globule of iron. Here a remarkable difference between the two metals is obſerved, the mangane ſe vitrifies, the iron perſiſts, and is formed into a regulus.

The regulus, when well fuſed, generally perſiſts in a dry place, but ſometimes undergoes ſpontaneous calcination, and falls into a browniſh black powder, which is found ſomewhat heavier than the perfect metal; yet, when freſh, contains ſo much phlogiſton as to produce inflammable air, on ſolution in vitriolic acid: this phlogiſton it loſes by time. The cauſe of this ſpontaneous reſolution is not yet ſufficiently explained; but it appears very probable, that, on account of the weakneſs of the fire, the particles ſometimes coaleſce ſo imperfectly, that when the dephlogiſtication again begins, they eaſily loſe their mutual connection: moiſture, but particularly the acceſs of aerial acid, aſſiſts this operation. A ſmall piece, put into a dry bottle well corked, remained perfect for the ſpace of ſix months, but afterwards,

afterwards, expoſed to the open air of a chamber for two days, contracted a brownneſs on its ſurface, together with ſo much friability as to crumble between the fingers: the internal parts, however, retained an obſcure metallic ſplendor, which diſappeared in a few hours;—a piece more fully impregnated with iron reſiſts the action of the air better.

(D) It melts readily with other metals, pure mercury excepted. Copper, united with a certain quantity of it, is extremely malleable; but upon the ſurface of this mixture, when poliſhed, ſcarce any traces of the red colour are to be ſeen: this mixture ſometimes by age produces a green efloreſcence. Tin very eaſily unites with mangaueſe; but zinc not without much difficulty, perhaps on account of its volatile and inflammable nature. White arſenic adheres to it, and by means of phlogiſton reduces it to a metallic form.

(E) Manganeſe, calcined by fire, yields a blackiſh calx; but if the ignition be continued for twelve days it acquires a dark green colour; ſometimes alſo it produces a white or a red calx, of both which we ſhall treat ſeparately (G). The black calx retains a very ſmall portion of phlogiſton, but the white abounds with it ſo much that it is ſoluble in acids.

All theſe varieties, in a common crucible, by means of a ſufficient degree of fire, run

run into a yellowiſh red glaſs, which is pellucid, unleſs too great a degree of thickneſs renders it impervious to the rays of light.

The black calx of mangane'ſe by a peculiar energy, when mixed with other ſubſtances, attracts phlogiſton, and exhibits ſeveral remarkable phænomena both by fire and ſolution; the chief of which we ſhall conſider, beginning with thoſe which occur in fuſion.

(F) In order to diſcover the genuine habits of this ſubſtance, we muſt employ the blow-pipe; for, by means of this inſtrument, we can diſtinctly ſee all the ſucceſſive changes occaſioned by fire, from the beginning to the end.

Let a globule of microcoſmic ſalt be fuſed upon the charcoal, and to it be added a ſmall portion of the black calx; let this mixture be fuſed, by means of the interior blue flame, for a few minutes, and it will yield a bluiſh red pellucid glaſs; but if the quantity of calx be greater, it is of a rich red. Let it be again fuſed, but for a longer time, and we ſhall find the tinge totally deſtroyed. Let the globule, which is now colourleſs, be ſoftened by the exterior flame, and the colour quickly returns, and may be again diſcharged by continued fuſion. The ſmalleſt particle of nitre too, added to the glaſs, inſtantly reſtores the red colour; whereas ſulphur, and the ſalts containing vitriolic acid,

acid, contribute to difcharge it; as alfo do the metallic calxes, although thefe, in proper quantity, communicate each its own particular colour.

The glafs globule, after being deprived of all colour, if fufed in a filver fpoon recovers its rednefs, which it retains notwithftanding a long continued fufion; inflammable additaments indeed extinguifh the colour, but this is eafily reftored by fufion, nor can it again be difcharged without a new addition.

Thefe changes are agreeable to the eye, and of themfelves very remarkable: upon confidering the whole, it will readily appear that the caufe of them is to be fought in the different quantities of phlogifton. Let us firft examine the moft fimple cafe:—the globule of microcofmic falt fufed, confifts of the phofphoric acid only, partly faturated with mineral alkali; the difengaged part muft therefore neceffarily attract phlogifton from the ignited charcoal, which is again taken from it by the calx of the manganefe: now this calx, by a certain degree of phlogifton, is reduced to fuch a ftate that it exhibits no tinge, almoft in the fame manner as the feven primitive colours when collected form the light of day, at once white and tranfparent; now, whatever dephlogifticates the glafs, deprived of this tinge, reftores the rednefs, and this is effected by the nitre and the exterior flame.

Thefe

Theſe changes cannot take place in the ſilver ſpoon, becauſe in this caſe the ſupport does not ſupply any phlogiſton, and therefore the colourleſs globule fuſed upon it is quickly deprived of the quantity of phlogiſton it had before imbibed by the ſurrounding air—a loſs which in this inſtance cannot be repaired, and therefore the globule continues red.

The additaments capable of deſtroying the colour are ſuch as naturally contain phlogiſton, ſuch as ſulphur and white arſenic; or at leaſt ſuch as eaſily take it up from the coal, ſuch as gypſum and the other ſalts containing vitriolic acid, which thus readily run into ſulphur. The metallic calxes too are of ſuch a nature that they take phlogiſton from burning charcoal, which they are immediately obliged to give up to the calx by means of its ſuperior attraction.

The phænomena above deſcribed and explained alſo take place with borax, but with ſome difference: the colour with microcoſmic ſalt is a bluiſh red; that with an equal quantity of borax, a yellowiſh red; but in both caſes, by ſaturation, the ſame intenſe red is obtained. By fuſion upon charcoal too the tinge is not deſtroyed ſo ſoon in the latter caſe, as borax attracts phlogiſton with leſs force than the phoſphoric acid does.

If a ſmall quantity of calx of manganeſe be added to an alkali, either vegetable or mineral, fuſed in a ſilver ſpoon, and the fire continued

continued for a few minutes, the globule ſoon becomes of a whitiſh blue; or, if any iron be preſent, it acquires a green tinge; by a larger quantity the colour is made more intenſe, even ſo far as to appear nearly black; but the maſs fuſes ſlowly, and, by being marked with ſpots, ſhews an unequal diſtribution. If to the fuſed maſs be added either powder of charcoal or white arſenic, the calx of the manganeſe is phlogiſticated and the colours periſh; hence it appears why common cryſtalline glaſs grows red by the admixture of manganeſe; but if the alkaline ſalt prevails in it, it contracts a violet colour.

Nitre fuſed in the ſpoon flows about; but, added in ſmall quantities to the alkaline ſalt, does not deſtroy its globular figure: in this caſe the colour is changed to green by the addition of a ſmall quantity of calx of manganeſe, on account of the calcined iron preſent in the blue maſs.

Many of theſe changes take place in a crucible, but not all: the red glaſs indeed, upon the addition of powdered charcoal, efferveſces, and is deprived of its tinge; but the ſalts containing vitriolic acid, and the ignoble metallic calxes (except white arſenic, which eaſily yields its phlogiſton) are of no effect; for although the veſſel be red hot, neither the acid nor the calxes are thereby ſufficiently loaded with phlogiſton, and that portion which they naturally contain, in this caſe is not ſeparated; the contact of ignited coal is neceſſary.

Theſe things being known, it will not be difficult to explain the uſe of manganeſe in the purification of glaſs; for the iron, which contaminates a vaſt number of bodies, adheres not only to the alkali, but to the ſiliceous earth of which the glaſs is compoſed. Now this metal, in order to enter the texture of glaſs, muſt be deprived of a certain quantity of phlogiſton; the great quantity, however, of that principle with which it is capable of entering glaſs, produces a green colour in the ſame way, as by ſolution in acids (particularly the vitriolic) it produces a green vitriol: yet this ſalt, on being repeatedly diſſolved, ſucceſſively loſes more and more of its phlogiſton, for that reaſon grows pale, and at length is changed into a browniſh red lixivium, which refuſes to cryſtallize. If now ſo great a portion of manganeſe be added by fuſion to glaſs, that on the one hand the phlogiſton occaſioning the green colour may be abſorbed, and on the other by means of that phlogiſton the calx be deprived of all colour, we ſhall have a glaſs colourleſs as water. Too great a proportion of manganeſe will impart its own colour, too ſmall a one will leave a part of the original green in the glaſs: the latter exceſs, however, is preferable to the former, for a very ſlight degree of green is not perceptible in glaſs, unleſs when it is ſo hot

as

as almoſt to liquefy; and this, upon cooling, becomes again entirely inviſible. But the iron, if too much dephlogiſticated, communicates a yellow hue, which cannot be removed by the calx of manganeſe, but like the green when weak, can only be perceived in the glaſs while hot.

(G) The habits of manganeſe, examined by ſolution, confirm and illuſtrate the former experiments.

The vitriolic acid, even when concentrated, attacks manganeſe in its metallic form, but much better when diluted with double or triple the quantity of water: innumerable bubbles ariſe, which when collected are found to be inflammable. It is diſſolved more ſlowly than iron, and leaves behind a black ſpongy ſubſtance, of the ſame figure as the metal; a ſmell is perceived ſimilar to that occaſioned by marine acid with iron: the ſolution is colourleſs, like pure water; and upon evaporation depoſits very bitter ſpathous cryſtals, which are clear and colourleſs; but on the addition of alkali lets fall a white precipitate, which we formerly called the white calx of manganeſe, and is now to be more accurately examined.

It readily appears that this white calx of manganeſe, or more properly white aerated manganeſe, is not ſaturated with phlogiſton, as it wants the reguline form; and that regulus of manganeſe during ſolution is deprived of a portion of its phlogiſton, is the leſs

 doubtful,

doubtful, as it is certain that during that process inflammable air is generated. This calx however retains precisely that quantity which is necessary to render it soluble in acids; and when this portion is dissipated by a white heat in open air, the calx grows black, and assumes the properties of the black calx, which we have been considering. Here we must observe, that a solution of manganese, much diluted, although with aerated alkali it affords a white precipitate, yet with the caustic alkali yields either at once a brown calx, or one which soon grows black in the open air; the reason is this:—aerated alkali yields the aerial acid to the falling calx, as is easily seen from the increase of weight, the effervescence of the precipitate with acids, and by pneumatic distillation: but in this case the acids fix the quantity of phlogiston necessary to solution, as is seen from hence, that the pure air contained in the atmosphere or in water, although extremely greedy of this principle, is yet in this case not able to separate it. But the white calx is easily taken up by all acids, and does not at all tinge the menstruum, unless it be sensibly mixed with iron: it follows naturally that the calx, precipitated by aerated alkali, should effervesce with acids; it is also to be observed, that the whiteness is the more perfect as the quantity of iron is less, as this foreign admixture sullies the colour by a yellow or a brown.

We

We now proceed to the calcined black manganese: this, when either old or well calcined, is only taken up in small quantity by boiling in vitriolic acid; nevertheless, if the menstruum be added by successive portions, each of which renders a little soluble, it may be gradually saturated; and then, with aerated alkali, deposits a white calx: this seems to indicate that the calx, though dephlogisticated, yet possesses a small quantity of phlogiston, which is insufficient for the solution of the whole; notwithstanding which, the menstruum may be sufficiently saturated by such particles as lie next adjoining to it: these, by means of the acid, are capable of taking the necessary phlogiston from the more remote, if the number of them be sufficiently great to supply the quantity of phlogiston which is requisite for solution.

A singular translation we have already found to take place in the via sicca; and that the same is the case, the circumstances now to be related will put beyond all doubt:—the calx thus exhausted altogether rejects the vitriolic acid, unless some substance charged with phlogiston be added, which phlogiston is, by means of the acid, transferred to the calx; thus, upon the addition of sugar, honey, gum, or other suitable substances, the solution may be promoted and compleated. Such of those substances as upon the abstraction of their phlogiston perifh (namely organic bodies) leave no other veftige of themfelves in the folution than the phlogiftication above mentioned. A fimilar effect is alfo produced by the metals, not only the imperfect, but, what is very extraordinary, even by gold itfelf: this efpecially takes place in the marine acid, but in all cafes the metallic calxes are eafily found in the folution. We have faid that phlogifton is eafily transferred, by means of the acids, to the black calx; and that this, when loaded with plogifton in proper quantity, is diffolved; and this we have affirmed not without reafon, for the calx, when boiled with fugar diffolved in water, is not fupplied with phlogifton, nor is the fugar changed, but remains complete; and when it is feparated by lotion the calx is found infoluble as before: but if an acid be alfo added, by its means the calx takes up quickly as much phlogifton as is neceffary to make it foluble; nay, the phlogifticated vitriolic acid, when poured upon the calx, foon lofes its fmell, and diffolves it readily without any affiftance.

Another method of folution has alfo been found out, which clearly fhews the great attractive force this calx poffeffes with refpect to phlogifton: thus, let the vitriolic acid be drawn off from the black calx feveral times with an heat approaching to ignition, in a glafs veffel, either open or fhut; after each operation let the foluble part be elixated with water, and at length nothing will

will remain: from whence then is derived the phlogiſton neceſſary for ſolution?—I anſwer, from the decompoſition of the matter of heat, which conſiſts of pure air, joined to a determinate quantity of phlogiſton. In order to ſhew that this is not bare conjecture, let the operation be performed in a cloſe veſſel to which is adapted a pneumatic apparatus; and towards the cloſe of the proceſs pure air is copiouſly produced, which is extricated while the phlogiſton is uniting with the calcined manganeſe. The calx is indeed of itſelf capable of decompoſing the heat, but cannot be rendered ſoluble without acids: if the acid, a little diluted, be drawn off only to dryneſs from one half its weight of black calx, water is able to take up by elixation upwards of one fourth of the calx: this water is of a beautiful red, and on due evaporation yields cryſtals of the ſame colour; this tinge indicates a deficiency of phlogiſton, a deficiency which, as has been already ſaid, may be ſupplied either by continuing the abſtraction to ignition, or by ſome ſuitable phlogiſtic additaments.

We have hitherto only conſidered the white and the black calx; it is proper now to beſtow ſome attention upon the other varieties: that which is produced by the ſpontaneous calcination of the regulus is at firſt of a duſky colour, but in the open air grows more brown; and in about fourteen days the weight is increaſed by 0,35, and is again

 diminiſhed

diminiſhed a few hundredths, on expoſure to heat. The humidity which had been attracted from the atmoſphere being now expelled, this calx, in proportion as it is more newly made, and leſs expoſed to fire, is the richer in phlogiſton, and is the more quickly diſſolved in vitriolic acid, with which it produces a bluiſh red colour: this elegant tincture, gently precipitated by means of aerated alkali, at length ſhews ſome red particles ſubſiding, which yet, collected on a filter, grow brown. It appears very probable that the red calx forms a ſort of medium between the black and the white, being more ſoluble than one, and leſs ſoluble than the other; and that the colour indicates the imperfect ſtate of the ſolution, for by the addition of ſugar it is diſcharged in a few minutes: to this claſs, doubtleſs, belong the red and brown ores of mangaueſe. The particles enveloped in tranſparent matrices afford very beautiful ſpecimens, more or leſs pellucid: thus the red ſpathous ore which is got at Klapperud, in Dalia, is found filled with zeolith; ſo that a ſmall piece, gradually put into an acid, is ſpoiled of the red calx, from the ſurface ſucceſſively inwards to the center, though the original form and magnitude remain: the remainder, upon examination, is found totally ſiliceous, for the argillaceous and calcareous parts of the zeolith matrix are extracted by the acid, together with the calcined manganeſe.

Both

Both the red and the colourlefs calx of manganefe are precipitated by a phlogifticated alkali of a whitifh yellow, unlefs the iron be fuperabundant.

It has already been obferved that the black calx of manganefe grows green in a red heat, which was firft remarked by the celebrated Rinman, upon making the experiment on a fpecies of black calx of manganefe, which muft yet be particularly diftinguifhed ; for though it confifts for the moft part of a black calx, yet it contains a number of heterogeneous particles, fuch as calcareous and filiceous earth, and terra ponderofa, fubftances which are always mixed with the Swedifh calx : this green calx is found concreted into loofe grains, is made white by the vitriolic acid, and corroded into a fubtile powder ; but very little is diffolved, even by the addition of fugar, nor is a red tinge ever produced.

Having thus fpoken pretty fully of the vitriolic acid, let us now briefly confider the other acids.

The nitrous acid diffolves the regulus with a certain effervefcence, occafioned by the generation of nitrous air ; yet a fpongy, black, and friable body remains, refembling molybdæna in its properties, fo far as the fmall quantity of the matter would permit experiments to be made. The other menftrua alfo exhibit a fimilar refiduum ; the folution is always brown, which is occafioned by the iron

iron adhering to the manganeſe—it ſcarcely acquires a red colour: the white calx is very readily taken up by the acid, during which operation the aerial acid is extricated, but no nitrous air appears. The ſaturated menſtruum has the appearance of water, unleſs iron be preſent: the black calx is very ſparingly diſſolved, yet a ſaturation is effected by means of a large quantity of the calx—phlogiſtic additaments complete the ſolution; but theſe are not neceſſary if the acid be employed in a phlogiſticated ſtate. In this caſe the decompoſition of heat ſeems to have leſs effect, as the menſtruum, being more volatile than the vitriolic acid, is diſſipated by a lower degree of heat. The green calx is acted upon in the ſame way as by the vitriolic acid: the ſolutions when pure depoſit no ſolid cryſtals, although the evaporation be conducted with the moſt cautious ſlowneſs.

Reguline manganeſe is diſſolved in the uſual manner by the marine acid, as is alſo the white calx; nay, the black is taken up in the cold by this menſtruum, and communicates to it a red colour. I had before conjectured that the red calx is richer in phlogiſton than the black, an opinion which is confirmed by a circumſtance which occurs here. Marine acid contains phlogiſton as one of its conſtituent principles; and the black calx, by means of a ſuperior attraction, ſeizes a part of this phlogiſton, and acquires a certain degree of ſolubility: but this

this union is very ſlight, and may even be deſtroyed by the ſimple affuſion of water: if, however, the red ſolution be expoſed to a digeſting heat for ſome hours, an inteſtine motion like an effervefcence takes place; the ſmell of dephlogiſticated acid is perceived, and the calcined manganeſe is taken up in ſuch a manner as to be only ſeparable by an alkali. The part of the acid which, by its phlogiſton, has rendered the calx ſoluble, puts on the appearance of a red vapour, and flying off manifeſts itſelf by a peculiar odour: if ſugar be employed, the decompoſition of the menſtruum is not neceſſary, nor is any ſmell of aqua regia perceived; other ſuitable phlogiſtic matters in the ſame way effect the ſolution of the black calx; nay, mercury itſelf, and even gold, neither of which yields directly to the marine acid, yet ſupply calcined manganeſe with their phlogiſton; and, being thus dephlogiſticated, are diſſolved in the menſtruum along with it.

Salited manganeſe ſcarcely yields diſtinct cryſtals, but only a ſaline maſs, which attracts the moiſture of the air: the precipitate by alkali is occaſionally either white, yellow, or black.

As the fluor acid, united with manganeſe, forms a ſalt difficult of ſolution, it is thence ſufficiently obvious, that the ſolvent power of that acid is extremely weak; for the particles, being ſurrounded by a ſaline cruſt, are freed

freed from the action of the menſtruum, yet, upon repeated additions, the acid may be ſaturated. If fluorated volatile alkali be added to a ſolution of manganeſe made in another acid, inſtantly a double elective attraction takes place, and a fluorated manganeſe falls to the bottom.

The ſame is true of the phoſphoric acid. The microcoſmic ſalt, added to manganeſe diſſolved in another acid, by a double affinity precipitates a phoſphorated manganeſe.

The power of vinegar is weak, yet it diſſolves the regulus in the way above deſcribed, and may even be ſaturated with the black calx, if that calx be added in large quantity. This combination yields no cryſtals; and after evaporation quickly deliqueſces again.

Not only reguline manganeſe, but alſo the black calx, is taken up by the acid of ſugar; but the ſaturated ſolution depoſits a white powder ſcarcely ſoluble in water, unleſs it be ſharpened by an acid. This ſalt grows black in the fire, but on addition of the ſaccharine acid, eaſily again acquires a milky colour. Manganeſe is precipitated in the form of cryſtalline atoms, by acid of ſugar, from its ſolution in vitriolic, nitrous, or marine acid.

The acid of tartar, which is ſimilar to this, takes up the black calx even in the cold, but the colour of the ſolution is a reddiſh brown; however this tinge is diſcharged

charged with effervefcence in a digefting heat; a part of the menftruum is therefore decompofed, and yields its phlogifton to the calx, as has been already obferved of the marine acid; befides, the tartarized vegetable alkali, added to any folution of manganefe, immediately throws down tartarized manganefe.

The circumftances already mentioned take place with the acid of lemons, which in this inftance poffeffes altogether the fame properties.

The weak aerial acid faturating water, attacks both the regulus and the black calx: the manganefe, thus diffolved, if not mixed with iron, feparates in the form of a floating white pellicle; by tincture of galls, or an alkali, it is precipitated white: if it is the regulus which has been employed, a peculiar fmell, refembling that of burning fat, is perceived.

A very minute portion of the black calx, added to an alkali in fufion, immediately tinges it of an elegant blue, or fometimes a green colour, if iron be prefent; hence it is that pot-afhes are fometimes found variegated with blue or green: the green folution in a clofe veffel gradually depofits its iron, and then, the yellow being difcharged, it becomes blue: expofed to the open air, the alkali attracts the aerial acid, and the black calx is depofited, a depofition which is more quickly effected by a few drops of a ftronger a ſtronger acid, or even by a large quantity of water; by this laſt the ſolution grows firſt violet, then red, and at length all colour vaniſhes, the black particles which before had been red being depoſited: theſe particles, while red, had been equally diſperſed through the clear maſs; but being more completely deprived of their phlogiſton, at length grow black.

(H) Eight parts of calcined mangaueſe, by a gentle heat in a glaſs retort, take up three of ſulphur, and produce a yellowiſh green maſs, which is acted upon by acids, diſſolving the metal with efferveſcence and an hepatic odour: the ſulphur which remains after the generation of the hepatic air may be collected on a filter.

Reguline manganeſe appears to reject ſulphur.

(I) Theſe properties evidently ſhew, that manganeſe differs conſiderably from all metals hitherto known; in fuſibility and colour it ſomewhat reſembles iron; in its ſtrength of attraction, ſpecific gravity, and in producing a colourleſs vitriol, it approaches to zinc; but in other properties is totally different.

Iron is malleable and magnetic when it retains the greateſt poſſible quantity of phlogiſton: during ſolution in acids it exhibits a green colour, but upon a greater dephlogiſtication it grows pale; and the laſt lixivium, which refuſes to cryſtallize, puts on

 a reddiſh

reddiſh brown appearance. The vitriol of his metal, diſſolved in water, is decompoſed ſpontaneouſly in an open veſſel, and ſeparates n ochre—this depoſition is accelerated by heat: the calx depoſited is of a reddiſh brown, or at leaſt reducible to that colour by a due degree of heat.

Zinc is of a white colour, eaſily fuſible, and inflammable by ignition in open veſſels, and burns with a moſt elegant flame, ſending forth white flowers; but in cloſe veſſels the metal, being volatile, riſes by the force of the fire: it forms with copper a yellow compound, which, when the relative quantities are properly adjuſted, reſembles gold: it is eaſily diſſolved in all the acids, whether it be reguline or calcined, and forms a colourleſs ſolution: it yields a white calx, which is not rendered black by a red heat of ſome minutes: and it never tinges glaſs red: theſe, and its other properties, readily diſtinguiſh it from manganeſe. The entire habit of the latter with phlogiſton is ſo ſingular, that it cannot eaſily be confounded with the other metals; for what metallic calx, except the black calx of manganeſe, is able to decompound marine acid and volatile alkali, nay to ſeparate the phlogiſton even from gold itſelf?— What other, when deprived of its phlogiſton, can form a blue ſolution with alkaline ſalts, and a red with acids, which it again loſes by means of phlogiſtic additaments?—

What

What other is there which, by the difference in the quantity of phlogiston, can exhibit colours so various and so distinct, namely, white, red, green, and black? It is generally thought that black calxes contain the greatest quantity of phlogiston, but in this case the black contains least of it.

Besides, manganese, though tortured in many different ways, could not be changed into iron or zinc, or any other known metal, but obstinately retained its own properties; therefore, until experiments, free from the least ambiguity, shall have shewn that this is derived from other metals, it must be considered as a distinct metallic substance, unless we wish to overturn the certainty of natural philosophy altogether, by indulging fallacious conjectures. The difficulty with which the martial inquinament is separated, indicates no more than the existence of a very intimate union. The regulus eliquated from the black manganese of Sweden, exposed in an Hessian crucible for a quarter of an hour (without any additament) to a violent heat, lost 0,33, which had separated in the form of a brownish yellow scoria. The regulus was not yet magnetic; and, by the addition of sugar, the acids extracted pure calx of manganese; at least, with phlogisticated alkali, no traces of Prussian blue could be discovered. The remainder of the regulus weighed 67 lb.; and, upon repeating the operation,

operation, the part which was magnetic weighed only 25 lb. and the black ſcoria was found contaminated a little with iron. This regulus, fuſed again, yielded only 17 lb. and diſſolved in acids, by the addition of phlogiſticated alkali, both white and blue particles were depoſited, the former of which appeared moſt numerous; ſo that we may conclude, that in 100 parts of mangancſe there are not preſent, of common iron, more than 0,08.

The method by which the quantity of iron may be accurately examined, will be deſcribed § VIII. B.

§ VIII. *Method by which Mangancſe, when mixed with Iron, may be diſtinguiſhed and ſeparated.*

The ores of iron and of mangancſe are very frequently loaded with both metals; and although the iron ores are often found without manganeſe, yet thoſe of the latter are ſcarcely ever free from the former. The calxes of theſe two metals are alſo frequently found together in the vegetable kingdom.

(A) In order to diſcover the preſence of manganeſe in iron quickly and eaſily, the blow-pipe may be employed in the manner above deſcribed (§ IV.); but no redneſs appears, if a particle of complete metal be added to the ſalt in fuſion, as the tinge is deſtroyed by the phlogiſton of the iron (§ VI. F and G). The purpoſe is generally better anſwered by a ſmall portion of the metal well calcined; but upon charcoal the metallic calx attracts phlogiſton from the ſupport, therefore the fuſion muſt either be performed in a ſilver ſpoon, or elſe the red colour muſt be induced by a ſmall piece of nitre. A perſon uſed to the proceſs will eaſily know the preſence of manganeſe, and even be able, from the phænomena, to judge of its quantity.

In a crucible too, the preſence of manganeſe is diſcovered without difficulty. To a piece of iron, weighing a few aſſay pounds, and made red hot, let there be added about five times the quantity of cryſtallized nitre; and let the ſame quantity be again added when the efferveſcence has ceaſed: if any manganeſe be preſent, a green ring will be found round the middle of the inſide of the crucible; if the quantity be conſiderable, it will not be neceſſary to add the nitre a ſecond time;—the crucible muſt be removed from the fire while the maſs is red hot.

(B) Let a determined weight of the iron ſuſpected to contain manganeſe be diſſolved in a large quantity of nitrous acid, let it then be evaporated to dryneſs, and at length made red hot: let the reſiduum be weighed, and put into diluted nitrous acid, together with a ſmall piece of ſugar; and if any manganeſe

 be

be preſent, after a few hours the menſtruum, when ſaturated with aerated alkali, will yield a white metallic calx, which may be thus totally abſtracted : let the remainder, which is totally deprived of mangaueſe, be elixated, dried to ignition, and finally again weighed—the difference of weight, before and after the extraction, will ſhew the quantity of calcined manganeſe ; and this being given, the correſponding quantity of reguline manganeſe is eaſily determined, as that metal gains 0,33 by calcination. The ſolution itſelf alſo, precipitated by a fixed alkali, affords a white calx, the knowledge of which eaſily determines the quantity of the reguline manganeſe ; for experiments ſhew that 100 parts of this metal diſſolved, yield 180 of white calx.

The white calx thus obtained is ſeldom entirely free from iron, as it is very difficult to deprive that metal ſo far of its phlogiſton, that the nitrous acid, eſpecially when phlogiſticated, cannot take up ſome portion of it : but if the white calx, obtained as above, be well calcined, and again diſſolved in nitrous acid, by means of the addition of ſugar, the iron remains for the moſt part undiſſolved ; at the beginning too, the martial inquinament, being weaker in attractive power, may be precipitated by a few drops of volatile alkali.

Iron, contaminated with manganeſe, if powdered and plunged into a ſolution of martial vitriol, is gradually depurated; for, in virtue of its ſuperior attraction, the acid ſeparates from the iron, and diſſolves the manganeſe.

§ IX. *Proximate Principles of the white Ores of Iron.*

Theſe things being premiſed, we are enabled to judge properly of the compoſition of our ores, namely, they always conſiſt of lime, iron, and manganeſe, but in proportions infinitely varied; for we ſhall paſs over in ſilence the foreign matters, which we have already mentioned as being ſometimes preſent (§ VI. B).

(A) The preſence of lime is indicated by the effervescence, more or leſs remarkable, occaſioned by the pulverized ore (§ VI. A); by its occaſioning an heat in water, when ſufficiently burned; by its ſeparating a cream (§ V. A); and by the whitiſh opacity occaſioned upon cooling, in the nitrous globules, when too much loaded with it (§ IV. B). Other circumſtances tend alſo to prove the ſame thing; but the humid ſolution (§ VI. D) it is which puts the matter beyond doubt. If any portion of the metal ſhould at the ſame time enter the menſtrua employed (which is generally the caſe) that part ought firſt to be precipitated by phlogiſticated alkali; and afterwards the lime, by an aerated alkali.

(B) Of

(B) Of the preſence of iron there is no doubt; the crude ore is ſometimes attracted by the magnet, which is almoſt always the caſe when it is burned; but ſometimes, even after burning, this property is concealed by the ſmallneſs of the quantity, the iron frequently not exceeding 0,02, which nevertheleſs is diſcovered in the ſolution by means of phlogiſticated alkali. The quantity of metal is diſcovered by reduction, either in the humid way or by fire, ſolution, and precipitation (§ V. E; VIII. B).

That iron, deprived of its metallic form, is preſent, eaſily appears, for the ore is ſeldom magnetic before roaſting; nor on ſolution does it generate inflammable air, when the menſtruum is vitriolic or nitrous acid: however, as the perfect ore yields without heat green ſolutions, except with the nitrous acid, and produces with the vitriolic acid a beautiful green ſalt, we may thence collect, that the deficiency of phlogiſton is in this inſtance not greater than in martial vitriol.

(C) The preſence of manganeſe is indicated by the moſt manifeſt ſigns, and that even in the ſtate of white calx, unleſs when injured by lapſe of time: theſe are, the blackneſs occaſioned by calcination, either ſpontaneous or produced by fire (§ IV. A; VII. G); the habits, when examined by the blow-pipe (§ IV. VII. F) and by other experiments, both by fire (§ V. VII. A, F)

 and

and by the humid way (§ VI. VIII. G). But what puts the matter entirely beyond doubt is, that the calx may be ſeparated, and ſeparately examined (§ VIII. B). White calcined manganeſe forms proportions of the whole maſs very unequal. From the regulus of Eiſenartz, 42 lb. in weight, 24 of white manganeſe is obtained (§ V. E); which weight alſo yields 13 lb. of regulus of manganeſe; the iron, therefore, is 42 — 13 = 29: and in 100 parts of this ore, of calcined iron, as in green vitriol, about 38, of aerated manganeſe 24, and of aerated lime 38. The ore brought from the mountain, which in Sweden is called the weſtern Silver Mountain, in the ſame way yielded 22 of calcined iron, of white calcined manganeſe 28, and of aerated lime 50.

§ X. *Uſe of the white Ores of Iron.*

It is well known to the ſkilful in thoſe matters, how excellent the ſteel is which is produced by the white ores; although that the foundation of this excellence is an admixture of manganeſe has heretofore been unknown. In the reguli formerly eliquated (§ V. F.) the manganeſe formed about one third, by which, not only the hardneſs was increaſed, but a ſilver ſplendor communicated. The beſt proportions in mixing the metals muſt be determined by various and repeated experiments.

Theſe

Theſe ores frequently contain iron in ſuch ſmall quantity that they cannot properly be denominated from that metal; one or two hundredths are certainly of no ſuch conſequence: in ſuch the calcareous earth abounds, which conſequently by roaſting is converted into quick-lime, but is black or brown, on account of the dephlogiſtication of the earthy baſe of the manganeſe. A black calx of this kind is got in the neighbourhood of Upland; this affords excellent mortar, which grows harder, and dries more quickly, than any other, even under water. This ſuperior excellence is rather to be attributed to the manganeſe than to the iron, as the calcareous ſtones, deprived of manganeſe, though containing the ſame portion of iron as thoſe of Lena, yet produce a mortar of a much inferior quality. We have calcareous ſtones in many places of Sweden, which grow black on burning, and which doubtleſs poſſeſs the ſame virtue.

We employ the black manganeſe in glaſs-houſes for purifying glaſs: how this acts has been already explained (§ VII. F). It is very probable that calcareous earth, loaded with manganeſe, and deprived of iron, ſuch as we have ſpoken of for building, may be applied to the ſame purpoſe.

DISSERTATION XX.

OF

NICKEL.

§ 1. *Hiſtorical Introduction.*

THERE is found in the parts of Germany which abound in metals, an ore which is called *kupfer-nickel*, ſometimes grey, but often of a reddiſh yellow colour, and poliſhed. This name it probably firſt got and ſtill retains from this circumſtance, that although it has the appearance of containing copper, yet not the ſmalleſt particle of that metal can be extracted from it, even by fire. The firſt account we had of it was from V. Hierne, in a book publiſhed in 1694, written in the Swediſh language, concerning the diſcovery of ores and other mineral ſubſtances.

Henckel

Henckel conſiders it as a ſpecies of cobalt or arſenic, alloyed with copper, and Cramer refers it to the arſenical or cupreous ores; but neither they, nor any other perſon (as they themſelves confeſs) were ever able to extract from it a ſingle particle of copper. Several other philoſophers acquieſced in this opinion, until that celebrated mineralogiſt Mr. Cronſtedt firſt undertook an accurate examination of this mineral, and by many experiments, which were publiſhed in the years 1751 and 1754, ſhewed that it contained a new ſemimetal, to which he gave the name of *nickel*.

Almoſt all the Swediſh mineralogiſts afterwards embraced this opinion, as alſo did many others, although the old opinion was not entirely deſerted; for ſome were led rather by vague conjecture and ſpecious appearance, than by ſatisfactory experiment; and Mr. Sage has lately attempted to eſtabliſh the former theory by chemical reaſonings and experiments. In the acts of the Royal Academy at Paris he deſcribed an analyſis of nickel which he had undertaken, and upon this grounds an opinion that the new ſemimetal is compoſed of cobalt mixed with iron, arſenic, and copper.

In order to decide upon this ſubject many experiments are neceſſary, and theſe I undertook with a mind totally free from any preconceived opinion; and though upon this occaſion the ſcarcity of the mineral prevented

vented me from entirely removing doubt, yet I truſt that ſo much of the truth has been laid open, that when a ſufficient quantity of this ſubſtance can be obtained, it will be found no difficult matter to eſtabliſh the truth in the moſt deciſive manner.

§ 11. *Eliquation of the Regulus.*

In order to obtain the regulus of nickel, the ore muſt be firſt ſubjected to roaſting, during which a quantity of ſulphur and arſenic, greater or leſs according to the nature of the ore, is expelled; ſo that it ſometimes loſes upwards of half its weight, but frequently not above 0,3. This ore, though long and completely calcined, does not always acquire the ſame colour, but in general becomes greener in proportion as it is more rich; ſometimes (eſpecially if ſuffered to lie at reſt) its upper ſurface is covered with green vegetations, ſomewhat of the form of coral, which are hard and ſonorous.

Let a double or triple quantity of black flux be added to the roaſted powder, and the mixture well fuſed in a forge, in an open crucible, covered with common ſalt, according to the uſual method.

The veſſel being broken, a metallic globule is found at the bottom, under the ſcoriæ, which are brown or black, or ſometimes even blue: the weight of the globule amounts

mounts to 0,1, 0,2, or at the moſt 0,5 of he crude ore.

This, however, is far from being pure; or although the roaſting be ever ſo violent nd long continued, yet a conſiderable quanity of ſulphur, but eſpecially arſenic, ſtill emains concealed in the regulus, excluſive of cobalt, and a great proportion of iron, which laſt is generally ſo prevalent as to nake the regulus magnetic; and this variey of heterogeneous matter is the cauſe why he regulus varies much, not only in reſpect to its fracture, the poliſhed ſurface of which is either ſmooth or lamellated, but alſo in regard to its white colour, which is nore or leſs yellow or red.

It is obvious from hence how neceſſary t is to depurate the regulus, if we wiſh to udge rightly of its genuine nature and properties: I have therefore undertaken a great variety of laborious proceſſes for this purpoſe;—to deſcribe them all circumſtantially would far exceed the limits of this Eſſay; I ſhall therefore only mention the moſt remarkable, and that conciſely; for in writing to metallurgiſts it is by no means neceſſary to deſcribe all the minute circumſtances attending an operation.

§ III. *The Regulus depurated by Calcination and Scorification.*

In order to diſcover the effect of repeated calcinations and ſcorifications, the following experiments

experiments were made with a certain regulus of nickel found in the Suabian collection of the Upsal Academy, which had been eliquated by Mr. Cronstedt, and whose specific gravity, taken by a very exact hydrostatic balance, was to that of distilled water as 7,4210 to 1,0000.

(A) Nine ounces reduced to powder were exposed in several dishes, for six hours, to an exceedingly vehement heat, under the dome of an assay furnace; by this the arsenic was first dissipated with a fœtid smell; a sulphureous odour was next perceived; afterwards a quantity of white smoke, without the garlic smell, which probably arose from the sublimation of the more dephlogisticated arsenic: when the heaps were hot they began to swell, and green vegetations sprang out from all the surface, resembling moss, or the filiform lichen; there remained at the bottom a powder of a ferruginous ash-colour. In this operation 0,13 were dissipated.

(B) Half an ounce of this calx, fused in a forge for four minutes, together with three times its weight of black flux, yielded a regulus the surface of which was reticulated, all the areolæ being hexangular, with exceeding slender striæ, diverging from a tuberculated center: it weighed 0,73 of half an ounce, was obedient to the magnet, and when scorified with borax left a blackish glass.

(C) This

(C) This regulus being again roaſted, firſt yielded a garlic ſmell, and after a viſible inodorous fume, together with vegetations as before.

(D) The roaſted powder being reduced by the black flux, and taken out of the veſſel, a ſmell of arſenic was again perceived: the fuſion was repeated with the calx and borax, and nothing appeared but ſome obſcure ſigns of cobalt.

(E) The regulus of nickel, roaſted a third time, yielded but little ſmell of arſenic; no vegetations appeared; and finally the metallic calx had rather a ferruginous than a green colour.

(F) After reduction in the fourth calcination nearly the ſame phænomena appeared.

(G) Reduction being performed with lime and borax, the regulus, when firſt fuſed, loſt much of its iron, which adhered to the black ſcoriæ; it ſoon acquired an hyacinthine colour without any remarkable mixture of cobalt; it was now but little obedient to the magnet, and its ſpecific gravity 7,0828.

(H) The regulus was again roaſted (the fifth time); but upon the gradual addition of powdered charcoal to the diſhes when red hot, a prodigious quantity of arſenic, which was before imperceptible, flew off in the form of ſmoke; for it is the nature of this ſemimetal, that unleſs there be preſent a certain quantity of phlogiſton, with which

it

it may unite, it does not yield to the action of fire, but remains fixed. The powder was treated in this way, until no more ſmoke or garlic ſmell appeared, although charcoal was again added.

(I) On reduction a regulus was obtained of a lamellated and tenacious texture, which yet, when the veſſel was removed from the fire, diffuſed an arſenical odour.

(K) The roaſting was therefore repeated a ſixth time, and continued for ten hours, and by powdered charcoal arſenic was expelled, diſtinguiſhable not by the ſight but by the ſmell; the colour of the metallic calx was obſcurely ferruginous, mixed with a green ſcarcely viſible.

(L) The reduction being effected with equal parts of the white flux, lime, and borax, a regulus was obtained, ſemiductile, highly magnetic, and ſoluble in nitrous acid, to which it communicates a deep green colour; yet there remains a blackiſh maſs which eludes the force of the menſtruum, which afterwards grows white, and, ſet upon a burning coal, flies off without any remarkable arſenical ſmell.

(M) The regulus was then ſix times fuſed with lime and borax; the ſcoria hence ariſing reſembled the hyacinth in colour, but a green metallic calx ſurrounded the regulus, which, as before, was obedient to the magnet, and, being ſemiductile, broke tenaciouſly,

tenaciously, that is, the broken part was rendered rough by extended threads.

(N) After all these roastings the regulus was exposed during fourteen hours to a very strong heat; after this powdered charcoal was added by degrees, without any dissipation of arsenic, or loss of weight: the colour of the roasted powder was ferruginous, with a very weak tinge of green.

(O) After reduction, a very small globule, still magnetic, was found among the scoriæ, which were much loaded with iron. Of this globule we shall speak more at large in § IV. I, &c.

§ IV. *Eliquation of the Regulus from the Ore of Los.*

The nickel ore which is got at the mines at Los, in Helsing, was examined and depurated in the following way:

(A) The roasting was performed in the usual way.

(B) As was also the reduction.

(C) The regulus was then calcined, and the powdered charcoal was added by degrees, until all the arsenical smoke had ceased, and the calx of nickel acquired a deep green colour.

(D) This being reduced, a magnetic regulus was obtained, which yet, when fused with lime and borax, was not obedient to the

the magnet, and yielded a ſcoria of a deep blue.

(E) Powder of charcoal was gradually added, during ten hours, to a regulus of this ſort ſufficiently calcined (if this be inſtantly done, the reguline particles readily coaleſce) by which means a quantity of arſenic was diſperſed, and a ferruginous powder, of a colour approaching to green, remained.

(F) After reduction with the black flux, lime, and borax, the ſcoriæ were tinged partly with iron, and partly too with the nickel;—the white regulus was ſtrongly attracted by the magnet.

(G) But afterwards, though phlogiſton was added abundantly to the maſs in the diſhes, for the ſpace of fourteen hours, yet neither ſmoke nor ſmell betrayed any ſenſible diſſipation of arſenic, nor was the weight diminiſhed; but, on the contrary, it was increaſed $\frac{1}{9}$ by the roaſting;—the metallic ferruginous calx was ſcarcely green.

(H) After the reduction the regulus was ſemiductile and magnetic.

(I) This, firſt fuſed with lime and borax, and afterwards united with that which was mentioned in the preceding (§ III. O) yielded a white ſemiductile regulus diſtinct, with the colour of green calx, and hyacinthine ſcoriæ.

(K) The ſame regulus was fuſed with ſulphur, and one-half its weight of the mineralized

neralized mafs, imperfectly roafted, was united by fufion with a portion of the crude mineral; this fulphurated nickel, well calcined, and reduced with a double quantity of black flux, yielded a regulus obedient to the magnet, which was nearly as refractory in the fire as forged iron.

As fulphur has a ftrong attraction for nickel, I had hopes that this mineralizing fubftance, not being fufficient to faturate both the nickel and the iron, would defert the latter, and adhere to the former; by which means, the iron entering the fcoriæ might be eafily feparated. The following paragraph will fhew the effect of this conjecture.

§ v. *Nickel depurated by Sulphuration.*

(A) 800 parts of the regulus of Cronftedt (§ III.) fufed with fulphur and a fmall quantity of borax, yielded a mineralized mafs of a reddifh yellow, amounting to 1700.

(B) One-half of this, when firft expofed to fire in a roafting difh, began to grow black, then the heat was increafed until vegetations arofe; the metallic calx now remaining weighed 652.

(C) This half, fufed with borax, and the other part not burned, yielded a fulphurated regulus of a whitifh yellow colour, in weight 1102.

(D) The fame regulus, by a calcination

which laſted for four hours, was firſt covered with vegetations, and afterwards, upon the addition of powdered charcoal, diffuſed a continued odour of arſenic; the weight of metallic calx, which was of a dilute green, was 1038.

(E) After reduction, a whitiſh yellow regulus was found, in weight equal to 594, ſemiductile, highly magnetic, and, at the ſame time, exceeding refractory.

(F) This was again fuſed with ſulphur, which being done, the weight was equal to 816; one-half of which, roaſted to greenneſs, united by means of fire with the other, ſtill ſulphurated, and in weight 509, ſcarcely obeyed the magnet. After a calcination of four hours, during which, by means of the phlogiſton, much arſenic flew off, the powder put on an aſh-colour, a little greeniſh, in weight 569, which by reduction yielded a regulus the ſurface of which was red, and which, upon breaking, appeared of a white aſh-colour, very friable, equal to 452; the ſpecific gravity of which was 7,1730.

(G) The regulus, mineralized a third time with ſulphur, was treated in the ſame way as before with powder of charcoal, ſo long as any veſtiges of arſenic remained, which required a vehement calcination for twelve hours. The powder then remaining was of an aſh-green colour, and weighed 364; but the regulus obtained by means of a reduction, effected by expoſure to a moſt

3 violent

violent heat in a forge for three-quarters of
an hour, was ſo refractory that it only ad-
hered imperfectly to the ſcoriæ, which were
of a diſtinct hyacinthine colour ; nor could
it be reduced to a globule by the addition
of borax, though urged by the ſame vehe-
mence of fire. The abſolute gravity of this
regulus was 180, but its ſpecific gravity
8,6666; and it not only adhered ſtrongly
to the magnet, but to any other piece of
iron, nay the ſmall pieces of it attracted one
another ; it was beſides ſo ductile, that
from a globule, whoſe diameter did not ex-
ceed one line, a plate of three lines in dia-
meter and upwards might be obtained by
the hammer : it was of a whitiſh colour,
mixed with a glittering kind of red : diſ-
ſolved in volatile alkali, it yielded a blue
colour, and in nitrous acid a full green.

One hundred parts of the ſame regulus,
beaten out into thin plates, after a calcina-
tion of four hours, were covered with a
cruſt in appearance martial, under which
was a green powder, and within a nucleus,
conſiſting of reguline particles unchanged :
the weight was increaſed by 5. The fria-
ble matter, reduced to powder, put on a
browniſh green colour, and after a calcina-
tion of four hours more, concreted at the
bottom in the form of a friable blackiſh
cruſt, which was ſtrongly magnetic, and
weighed 100 ; the cruſt was afterwards
comminuted, and roaſted for three hours,

with the addition of powdered charcoal, yet neither were any veſtiges of arſenic diſcovered, nor was the magnetic power deſtroyed; but the weight was now 105, and the colour little changed. This powder, fuſed for an hour with lime and borax, yielded a regulus of 72 lb.; this was red, angular, ſemiductile, and altogether magnetic, the ſpecific gravity of it was 8,8750. The ſame globule, diſſolved in aqua regia, was indeed precipitated by martial vitriol, as if loaded with gold; but the ſediment was very eaſily ſoluble in nitrous acid, hence it appears not to be gold. But moſt of the reguli which we obtained, ſhewed no ſigns of precipitation with martial vitriol; hence it clearly appears, that even if gold be ſometimes preſent, yet it is not always the caſe.

(H) 800 parts of the ore of nickel, which is found in Saxony at Johan-Georgenſtadt, roaſted for fourteen hours, and freed as much as poſſible from arſenic, by means of powdered charcoal, loſt 248 of their weight. After reduction, and the firſt mineralization performed in the uſual way, it was remarkable, that the latter ſulphurated regulus, which before calcination weighed 230, afterwards was equal to 242; and after another ſulphuration of the ſame kind in the laſt calcination, had its weight increaſed from 70 to 78: the regulus laſt obtained was equal to 22, obedient to the magnet poſſeſſing poffeffing a fpecific gravity of 7,3333, and yielding with borax an hyacinthine glafs: it was with difficulty calcined, but at length fell into a greenifh powder, and with nitrous acid yielded a folution of the fame colour.

(I) The procefs of mineralization and calcination defcribed in (H), was repeated with 100 parts of the ore of Los, and that without any increafe of weight: the regulus finally obtained was in abfolute gravity 1, in fpecific gravity about 8; it tinged borax of an hyacinthine yellow, and nitrous acid of a green colour.

§ VI. *Nickel depurated by Hepar Sulphuris.*

As it appears from experiment, that cobalt is more eafily diffolved than nickel, by hepar fulphuris, and that thefe fubftances may thus to a certain degree be feparated in the fire; a fufpicion arofe, that unequal degrees of affinity might produce the fame effect with iron and nickel.

(A) 58 parts therefore of regulus of nickel, which had before been fulphurated (§ V. G), fufed with 1800 of faline hepar fulphuris, then diffolved in warm water, filtered through paper, and precipitated by an acid, yielded a powder, which, roafted in a difh till the fulphur was confumed, was found of an afh-colour, and weighed 35.

 (B) The

(B) The residuum, which could not be dissolved in warm water, being freed from sulphur by means of fire, was also of an ash-colour, and weighed 334.

(C) This residuum, reduced by the black flux, yielded a friable regulus, which was indeed but little magnetic, yet, when fused again with borax, exerted that property (which had before been weakened by the sulphur) in a higher degree.

(D) The same experiment was tried with a calcareous hepar, according to the direction of Mr. Beaumé—viz. calx of nickel, gypsum, colophony, and white flux, were taken in equal proportions; these, mixed and fused, yielded a powdery, squamous, reguline mass, which, when fused with borax, produced a regulus possessing the properties of nickel (but not entirely destitute of cobalt), which obeyed the magnet, and even after two solutions in nitrous acid, and various reductions by fusion with borax, did not part with its iron; it also retained the sulphur obstinately.

(E) Regulus of nickel was dissolved, in the via sicca, by a saline hepar sulphuris, and upon the addition of a quantity of nitre, sufficient only to destroy a small part of the hepar, the regulus which had been suspended by it was separated and fell to the bottom. This regulus of nickel, upon examination, appeared more pure, and generally, at least for the most part, deprived of of cobalt, but ſtill containing iron. In like manner nickel is always very diſtinctly precipitated by regulus of cobalt, as this latter is attracted more powerfully by the hepar ſulphuris.

Nickel diſſolved by ſaline hepar ſulphuris in fuſion, may be precipitated by the addition of iron, copper, tin, or lead, and even by cobalt: the regulus obtained is ſcarcely ever attracted by the magnet; but whoever concludes from thence that no iron is preſent, will be deceived; for this metal (the regulus of nickel), when properly freed from the heterogeneous matters which impede its action, acknowledges the magnet's power very plainly.

§ VII. *Nickel depurated by Nitre.*

Finally, Nitre, which attracts phlogiſton more powerfully than any other ſubſtance hitherto known, was employed; it was hoped that this would more eaſily ſcorify the heterogeneous matters, becauſe nickel ſeems both to loſe its phlogiſton more ſlowly, and to recover it more quickly, than thoſe matters.

(A) One part of Cronſtedt's regulus was added to twelve of nitre, ignited in a crucible, and kept in an equable degree of heat for the ſpace of an hour; at firſt ſome weak flaſhes appeared, probably from the reſiduum of the ſulphur; afterwards a large quantity of arſenic was thrown out; finally, the ſides were covered with a blue cruſt, occaſioned by the cobalt, and a green matter remained at the bottom. This fuſed again for an hour, with twelve parts of nitre, tinged the internal ſides of the veſſel of a green colour; and finally a browniſh green maſs, much leſs in quantity than in the former operation, was found collected at the bottom.

The green matter, treated in the ſame way a third time, for two hours, left a grey ſcoria at the bottom, which, with black flux, yielded no regulus.

Another portion of the ſame regulus, fuſed with nitre in the ſame way, was diſſolved and became green; yet, being freed from the alkaline ſalt by means of water, neither did this yield any regulus with black flux, but ſcoriæ of an hyacinthine colour, mixed with blue; which tinged nitrous acid of a green colour, concreted into a jelly, and upon evaporation left behind a greeniſh calx.

(B) Another portion of Cronſtedt's regulus was kept ſome hours in the crucible, with ſixteen parts of nitre; by this means, at firſt all the arſenic was ſeparated, then the phlogiſticated nitrous acid flew off, and finally blueiſh green flowers penetrated the ſides of the veſſel. The maſs being freed from alkali by water, and dried, was of a

dilute

dilute green, and tinged borax of a greenish brown.

This was again treated in the same way with 12 parts of nitre; and after edulcoration yielded a powder still green, which, reduced with $\frac{1}{2}$ black flux, $\frac{1}{8}$ lime, and $\frac{1}{8}$ borax, in half an hour yielded a yellowish white regulus, both magnetic and malleable, and possessing all the properties of nickel; its specific gravity was 9,000. The inflammable ingredient was used in small quantity, that if possible the iron might enter the scoriæ.

(c) One part of the ore of los was strongly ignited in a crucible, for the space of an hour, with eight parts of nitre, and a detonation more distinct than with the regulus took place at first. The metallic calx, which was separated from the saline matter by water, was of a brown ferruginous colour, similar to that which is wont to remain after calcination with charcoal-dust. This by reduction yielded an ashen-white regulus, tenacious and magnetic, of the specific gravity 8,5573: the scoriæ were black. The regulus reduced to powder, and fused with 12 parts of nitre, lost much cobalt; and yielded a green calx, which, on reduction with double its weight of black flux, and $\frac{1}{2}$ quick-lime and borax, left nothing but distinct globules of nickel, tenacious and magnetic.

(D) One

(D) One part of Cronſtedt's regulus was fuſed for three hours with 8 parts of nitre, in a crucible, to the cover of which an open glaſs tube was ſo adapted that the aſcending vapour might be collected there: the operation being finiſhed, white arſenic was found in the upper part of the tube; but in the lower a powder of a brown aſh-colour, a little green, which tinged borax of an hyacinthine colour, and yielded a regulus ſo loaded with arſenic as not to be magnetic. The ſides of the crucible were blue; but the ſaline green maſs at the bottom on elixation depoſited a green calx, which was kept ignited with 12 parts of nitre for the ſpace of an hour, and became partly blue, partly green: but afterwards, when only $\frac{1}{4}$ of the green reſiduum was treated in the ſame way, the whole appeared blue: yet the green reſiduum was diſſolved in nitrous acid, and rendered borax of an hyacinthine colour; ſo that it conſiſted of nickel ſurrounded by a blue cruſt.

(E) As the experiments above related ſhew, by means of nitre, the ſmalleſt traces of cobalt, which otherwiſe would be completely latent, I examined the various niccoline products in diſhes, with the addition of nitre, under the dome of an aſſay furnace: namely, 1ſt. The regulus (§ IV. I.) which was a little blue. 2d. The regulus previouſly diſſolved in volatile alkali (§ X. A.) which manifeſted a conſiderable quantity

quantity of cobalt that had lain hid before. 3d. The regulus previoufly fulphurated, which affumed a bluifh pellicle. 4th. The globules (c), which fent forth a copious quantity of blue flowers. 5th. The fublimate of the preceding article (D), which fhewed exceeding weak figns of a blue: and finally, 6th. The hyacinthine fcoriæ of nickel, which were of a beautiful blue, yet contained fo little cobalt that all the colour could be difcharged from the glafs of borax tinged by it, by means of the blow-pipe; which yet, on the addition of a fmall quantity of nitre, becomes blue: for the nature of metallic calxes is fuch, that they tinge glafs the more deeply as they are more fpoiled of phlogifton; and, on the contrary, when they recover their principle of inflammability to a certain degree, all tinge vanifhes. The former of thefe effects may be produced by nitre, the fecond by fufion on charcoal, provided the calx be fo fmall in quantity, and fo greedy of phlogifton as to be faturated by it from the coal; otherwife thefe hyacinthine fcoriæ tinge acids of a green colour, and are precipitated like nickel by phlogifticated alkali.

§ VIII. *Nickel depurated by Sal Ammoniac.*

As iron is eafily fublimed by means of fal ammoniac, it was tried, in the following manner,

manner, whether nickel could by this method be freed from iron.

(A) A calx of nickel, ſo much freed from cobalt as not to tinge borax with the ſlighteſt blue, was mixed with double its weight of ſal ammoniac, put into a cucurbit covered with an head, and expoſed to a fire gradually increaſed until the glaſs grew red: the bottom was ſtained with a very deep hyacinthine colour, and exhaled flowers, which adhered to the ſides; theſe were partly aſh-coloured, and partly white; which laſt did not riſe ſo high as the former.

The reſiduum exhibited two ſtrata, the upper of which was yellow, ſquamous, and ſhining, like aurum moſaicum: it yielded with borax an hyacinthine glaſs, but no regulus; after a few days it liquefied in the air, acquiring the conſiſtence of butter, and a green colour. This reſiduum, with warm water, ſhewed the ſame properties and colour as calx of nickel; and the ſolution, which was green, became blue with volatile alkali, but with tincture of galls ſhewed no veſtiges of iron; a circumſtance which alſo took place in the flowers.

The inferior ſtratum contained a calx of nickel not yet converted into vegetations, and ſomewhat contaminated with marine acid: the colour was blackiſh, and, at the bottom, of a ferruginous brown. With borax it yielded an hyacinthine glaſs, and a friable

friable regulus of a reddiſh white, and ſcarcely magnetic.

(B) A part of the inferior ſtratum (A), ſublimed with double its quantity of ſal ammoniac, with the ſame degree of heat as before (which preciſe degree was employed in the following) yielded an hemiſphere of an hyacinthine colour, and flowers of a very fine white; but the reſiduum was of a ferruginous brown, greeniſh on the upper part towards the ſides of the veſſel.

(C) To a portion of the inferior ſtratum reduced, was added 20 parts of ſal ammoniac, which were ſublimed in a retort; a blackiſh powder remained, which, as well as the bottom of the veſſel, by calcination put on a green, and by ſcorification an hyacinthine colour.

(D) To the powder remaining (C) was added a double quantity of ſal ammoniac, which was again ſublimed extremely white, and the greeniſh maſs which remained was of a ferruginous brown at the lower part.

(E) Sublimation was performed with the reſiduum of (D) and a double quantity of ſal ammoniac, and yielded as before exceeding white ammoniacal flowers; and the reſiduum, which was very green, was altogether like a calx of nickel diſſolved with the ſame colour in nitrous acid, and by reduction yielded a regulus of nickel, white, brittle, and very little magnetic.

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In each ſublimation the volatile alkali roſe firſt, then ſal ammoniac, and finally a portion of marine acid came over into the receiver.

§ IX. *Nickel depurated in the humid Way by nitrous Acid.*

After ſo many experiments made by the via ſicca, many others were tried in the way of ſolution, beginning with the cryſtallized ſalt, (which, being compoſed of nitrous acid and nickel, ſhall be called nitrated nickel) by which, if poſſible, the iron being dephlogiſticated, would ſeparate from its menſtruum.

(A) Nitrated nickel, ſprinkled during calcination with charcoal-duſt, ſent forth a large quantity of arſenic, and after reduction yielded a regulus, grey, ſemi-ductile, and magnetic.

(B) This being again diſſolved in nitrous acid, precipitated by fixed alkali, and reduced, yielded a brittle regulus.

(C) The ſame being a third time diſſolved, yielded a regulus ſemi-ductile and magnetic.

(D) This operation was repeated a fourth time.

(E) The regulus, when diſſolved a fifth time, was ſo much diminiſhed, that the white calx obtained by precipitation could not be any farther examined.

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In all theſe ſolutions a blackiſh reſiduum preſented itſelf, which, when ſuffered to remain in the acid, grew white by degrees; but when edulcorated, and laid on a burning coal, exhaled a ſulphureous ſmoke, and left a black powder ſoluble in nitrous acid.

§ x. *Nickel depurated by Means of volatile Alkali.*

In order to diſcover the effect of cauſtic volatile alkali, in depurating nickel, a portion of the regulus of Cronſtedt, diſſolved in nitrous acid, precipitated by fixed alkali, edulcorated, and dried, was treated in the following manner:

(A) 487 parts of this calx, immerſed in a ſuperabundance of volatile alkali, after twenty-four hours yielded a reſiduum = 50, of a blackiſh green, and a ſolution of a blue colour, which, when filtered and inſpiſſated to dryneſs, yielded a powder of a light blue colour = 282: this, reduced with black flux, produced a regulus, white, ſemi-ductile, and highly magnetic, = 35, and whoſe ſpecific gravity was 7,0000: the ſcoria which remained was a light red, but, mixed with borax, put on an hyacinthine colour, which yielded a regulus = 30. This regulus, united with the former by means of fire, was very refractory, ſo that even with the addition of borax it could not be fuſed by the blow-pipe: during calcination,

cination, with an abundant addition of charcoal-duſt, it did not ſend forth a ſmell either arſenical or ſulphureous : in a following reduction it yielded an hyacinthine ſcoria, and the remaining flocculi, diſſolved in nitrous acid, formed a very green ſolution, which, upon addition of volatile alkali, let fall a powder of the ſame colour.

(B) From 50 parts of the blackiſh green reſiduum was obtained a regulus of a clear white colour, brittle, ſquamous, but little magnetic, = 13, and of a ſpecific gravity = 9,3333. A ſcoria of an obſcurely blue colour, the upper part of it hyacinthine, was found at the bottom of the veſſel. The regulus was eaſily fuſed, and tinged borax firſt of a blue, then of an hyacinthine colour, upon which it grew more ſtrongly magnetic : by the aſſiſtance of heat it diſſolved in nitrous acid, and was of a beautiful blue. During this ſolution a black powder appeared, which firſt floated like flocculi, but became white, and fell to the bottom ; and after edulcoration, being expoſed to the fire, was for the moſt part diſſipated with a ſulphureous ſmell ; but there ſtill remained at the bottom a little maſs of a brown colour, ſoluble in volatile alkali : this ſolution was precipitated by phlogiſticated alkali, and a powder thrown down of the colour of calx of nickel ; this ſoon grew blue with volatile alkali.

Hence,

Hence, therefore, it appears, that nickel is eaſily and totally diſſolved in the volatile alkali, unleſs the efficacy of the menſtruum be obſtructed by the preſence of ſulphur.

§ XI. *Nickel can ſcarcely be obtained in a State of perfect Purity.*

Upon conſidering all the experiments above related, it eaſily appears, that it is ſcarcely poſſible to obtain a perfect and compleat purification of nickel from all heterogeneous mixture, by any means, at leaſt, hitherto known. The ſulphur is with difficulty expelled by calcinations and ſolutions (§ III. L; IX. and X.); arſenic adheres ſtill more ſtrongly (§ III. and IV.); but by means of charcoal-duſt and nitre is entirely expelled (§ III. N; VII. B); cobalt adheres the moſt pertinaciouſly of all, for by the addition of nitre its preſence has been detected even in products where it could not by any other method. No doubt its quantity had been ſo much diminiſhed by the nitre, that in ſolution it was totally imperceptible (§ VII. D), would ſcarcely tinge borax, and the tinge which is communicated is diſcharged with the blow-pipe, by the phlogiſton of the charcoal; all which circumſtances (as the colour of cobalt is very rich) demonſtrate its being preſent in exceedingly ſmall quantity (§ VII. E): but I am the rather inclined to think, that even

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this ſmall portion may be ſeparated; becauſe it is certain that the laſt productions of the blue colour are not to be aſcribed to cobalt but to manganeſe, as we ſhall demonſtrate more clearly hereafter (§ XII.); yet in practice the ſeparation is extremely troubleſome; for theſe reliquiæ, extracted by the nitre, envelop the nickel itſelf (which in this operation becomes very ſpongy) and adhere ſo cloſely to it, that mechanically they cannot poſſibly be ſeparated, and ſcarcely by menſtrua, as both the ſubſtances are thereby diſſolved: by fire too they enter the ſcoriæ; at leaſt in theſe two methods ſo little difference is diſcernible, that unleſs a large quantity together be ſubjected to the operation, all the nickel vaniſhes together with the cobalt.

In the preſent caſe then the iron alone remains, and the quantity of this cannot be diminiſhed beyond certain limits; the magnet readily diſcovers its preſence, and not only the reguli, tried in different ways, readily adhere to it, but ſome of them actually acquire a magnetic power (§ V. G), a circumſtance highly worthy of obſervation: but the tenacity and difficulty of fuſion, which increaſe the more as the operations are longer continued upon the nickel, plainly ſhew that no hope remains of ſeparating the iron; ſo that neither the ſcorifications, nor the ſal ammoniac (§ VIII.), nor the nitre, nor the nitrous acid (§ IX.), nor, finally, the volatile alkali

alkali (§ x.), have effected this purpofe; although Juncker fays, that nitre attacks iron fo powerfully that from a pound of fteel filings, detonated with an equal quantity of nitre, then fufed and elixated, no more than half an ounce of crocus is obtained.

Befides thefe heterogeneous matters, bifmuth is alfo fometimes prefent; but this is very eafily feparated; for if the folutions made in acids be fufficiently diluted with water, the menftruum is fo much weakened, and the calx of bifmuth falls to the bottom like a white powder.

§ XII. *Whether Nickel be a diftinct Metal.*

It may now be properly enquired, whether nickel be a diftinct metal, or whether it be a mixture made by the hands of nature, from others intimately united?—We have already obferved that arfenic, copper, cobalt, and iron, have been by various authors confidered as its proximate principles.

With refpect to arfenic, we may very fafely exclude it from the number, as the experiments above defcribed fhew that it may be entirely expelled.

It cannot be doubted but that copper is prefent in fome ores of nickel, and therefore may eafily be mixed with the regulus; but the greater number are entirely without it. It is true that nickel is totally foluble in volatile alkali, and that this fo-

 lution

lution is of a blue colour (§ x. b); but if this argument held, there would be nothing found here but copper; and if this were the caſe very different phænomena would appear from thoſe which the nickel produces. That both theſe ſubſtances form with volatile alkali ſolutions of the ſame colour, no more proves the identity of theſe ſubſtances, than does the yellowneſs of the ſolution both of gold and iron in aqua regia, prove the identity of thoſe metals. Nickel and copper agree alſo in this property, that they are both precipitated from acids, and from volatile alkali, by iron; but in the manner of this precipitation a conſiderable difference appears. Let a piece of poliſhed iron be plunged into a ſolution of nickel, and a yellow pellicle of nickel will by degrees adhere to it; which diſappears upon touching, and ſoon grows black, unleſs the acid be well ſaturated or ſufficiently diluted with water. A ſimilar precipitation is obſerved if zinc be uſed inſtead of iron; but in ſolution of copper ſo much diluted that the precipitation on iron may be nearly ſimilar to that of nickel, zinc is immediately covered with a cruſt of the colour of mountain braſs.

The experiments above deſcribed ſufficiently ſhew that cobalt does not belong to the eſſence of nickel (§ x. xiii. k); yet to theſe we ſhall add the following:—Nickel, diſſolved in hepar ſulphuris, is precipitated by by cobalt; with what juſtice then can we affirm them to be one and the ſame? In the ſame way, nickel tinging borax or microcoſmic ſalt, in the via ſicca is thrown down by the addition of a proper quantity of copper; but this is not the caſe with cobalt. Theſe circumſtances are ſo remarkable as of themſelves to baniſh all doubt. But with the acids a remarkable difference conſtantly occurs—1ſt, Cobalt tinges all theſe menſtrua of a red colour, and yields cryſtals either of a yellow or bluiſh red; but nickel produces ſolutions and concretions of a fine green; it ſometimes happens indeed that the red ſolutions yield greeniſh cryſtals; but this is to be attributed to nickel mixed in ſmall proportion with the cobalt. 2d, Cobalt, united with marine acid, affords a ſympathetic ink; but depurated nickel does not. 3d, Cobalt, diſſolved in volatile alkali, is red; but nickel, diſſolved in the ſame alkali, is blue. 4th, Cobalt does not, like nickel, ſeparate, upon the addition of arſenical acid, a powder difficultly ſoluble. Many other points of difference there are, which may be paſſed over in ſilence.

Iron therefore only remains; and indeed there are many and weighty reaſons which induce us to think that nickel, cobalt, and manganeſe, are perhaps to be conſidered in no other light than modifications of iron.

And firſt—in general we obſerve, that unequal portions of phlogiſton, united to the ſame iron, change its qualities in a remarkable manner: for inſtance, how very much do the different kinds of iron and ſteel differ? It is then to be obſerved, that nickel, cobalt, and mangancſe, whatever operations they may be ſubjected to, are ſo far from being deprived of iron, that on the contrary they thereby become more ductile, magnetic, and refractory. Again, the various colours which nickel, cobalt, and manganeſe exhibit, both by ſolution and by fire, are alſo exhibited by iron. Cobalt and manganeſe occaſion a red colour in acids, and the latter in glaſs; nickel and manganeſe occaſion an hyacinthine colour when fuſed with borax; a green is produced in acids by nickel, as alſo by its calx, and by manganeſe (M), when long and ſtrongly calcined; and it often leaves behind a ſcoria of the ſame colour, if the reduction be performed with a ſaline flux. Finally, cobalt occaſions a blue or rather a violet colour in glaſs; and the ſame is true of manganeſe diſſolved in fixed, and nickel in volatile alkali.

Iron too exhibits all theſe varieties; for the acids take up this metal of a green colour, ſo long as it contains a certain quantity of phlogiſton; but, in proportion to the diminution of this principle, a yellow, a red, or a browniſh red colour is produced. It tinges glaſs, in the ſame manner, green, yellow, black, or red. If expoſed to the fire for many hours together, with nitre, the bottom and ſides of the crucible, it is true, tranſude ſaline flowers, either blue, greeniſh blue, or greeniſh purple; but an efflorescence of the ſame kind is occaſioned by nitre alone; for this ſalt, by a long-continued fire, penetrates the veſſels, and immediately upon contact of ignited phlogiſton is decompoſed, and the alkaline efflorescences are made blue by the mangaueſe, which is always preſent in the circumjacent aſhes; theſe verge more to a green in proportion as the crocus martis is more copious; beſides, iron itſelf is often found mixed with manganeſe.

From hence, therefore, it appears, that the blue flowers, which were expelled from nickel by means of nitre, are the produce of manganeſe, as theſe impart to glaſs nothing of the cobalt colour; beſides, in the mineral kingdom we find the nephritic, ſmegmatic, ſerpentine ſtones, and jaſpers, clays called from their colour *terres verdes*, and other green ſtones, *lapis lazuli*, native Pruſſian blues and other blue ſtones, together with many diverſities of yellow and red, all deriving their colour from iron.

Whoever rightly conſiders theſe circumſtances will think it not an improbable conjecture, that theſe ſemi-metals are derived from iron, of which they cannot be entirely deprived; and from hence will take occaſion to examine this opinion by new experiments and obſervations, which may either

 ſerve

ſerve to eſtabliſh or overturn it. In the mean time we ſhould be carefully on our guard againſt ſuch glimmering lights, which are generally fallacious. So long as no one is able to produce any of theſe metallic bodies from pure iron, and to explain, in a clear and intelligible way, the proceſs by which manganeſe, cobalt, or nickel, may at pleaſure be generated, ſuch vague ſuſpicions muſt give way to phænomena and properties which are conſtant, and the ſubſtances themſelves continue to be conſidered of an origin altogether diſtinct and peculiar to themſelves. It is ſufficient for our purpoſes, that theſe metals poſſeſs diſtinct properties, and always preſerve their own peculiar nature, until we ſhall be better inſtructed by faithful analyſis and ſyntheſis. There is no doubt that many metals, which have been a long time known and acknowledged to be diſtinct ſubſtances, would ſcarcely have endured more ſevere trials than nickel does. By the ſame rule, therefore, ſuch metals may be alledged to be compounded. If the geneſis of natural productions was to be eſtabliſhed by fancied metamorphoſis, the whole truth and certainty of natural philoſophy muſt ſoon be overturned. So long as plauſible conjectures are ſubſtituted for opinions formed on the ſure baſe of experiment, we ſhall always embrace the ſhadow for the ſubſtance.

§ XIII. *Syn-*

§ XIII. *Synthetical Experiments.*

Although the ſynthetical experiments which I undertook with intent to diſcover the origin of nickel, were in that view ineffectual, yet I think it proper to relate the principal of them, that the way may be more eaſy to others. The ſpecific gravity of the copper, iron, cobalt, and white arſenic, employed, were 9,3243, 8,3678, 8,1500, and 4,0000, reſpectively.

(A) Equal parts of copper and iron, united by fuſion with black flux, yielded a red maſs, whoſe ſpecific gravity was 8,5441, which tinged nitrous acid firſt blue, then green, afterwards yellow, and at length an opake brown.

(B) Two parts copper, and one of iron, united, had a ſpecific gravity equal to 8,4634. The mixture yielded firſt a blue, then a green ſolution.

(C) Equal parts of copper, iron, and cobalt, yielded a regulus of the ſpecific gravity 8,0300, which imparts to the menſtruum a brown colour.

(D) One part of copper, one of iron, and two of arſenic, formed a brittle mixture of a ſpecific gravity equal to 8,0468, which formed a blue ſolution.

(E) One part of copper, one of iron, two of cobalt, and two of white arſenic, yielded a brittle compoſition of a ſpecific gravity equal

equal to 8,4186, which gave a browniſh red ſolution, and in part precipitated ſpontaneouſly.

(F) One part of copper, one of iron, four of cobalt, and two of white arſenic, united by fuſion, formed a maſs of ſpecific gravity equal to 8,5714: the regulus, diſſolved in nitrous acid, was as in (E), but more red.

(G) One part of copper, one of iron, four of cobalt, and two of white arſenic, acquired a ſpecific gravity equal to 8,2941; they were diſſolved with a red colour, and depoſited a ſediment.

(H) One part of iron, and four of white arſenic, fuſed, were diſſolved with a yellow colour; and, on the addition of phlogiſticated alkali, immediately yielded a Pruſſian blue.

All theſe mixtures, expoſed to the fire, left a calx, not green, like that of nickel, but brown, black, or ferruginous.

(I) One part of copper, eight of iron, ſixteen of white arſenic, and four of ſulphur, united by fire, on the addition of black flux, yielded a maſs, which, though frequently calcined and reduced, yielded nothing but a ferruginous or brown calx: with nitrous acid it acquired a greenneſs, but on the addition of phlogiſticated alkali, depoſited a Pruſſian blue.

(K) Many experiments were alſo tried in the way of ſolution; one of which it will be ſufficient to mention.

One

One part of iron was diſſolved in ſix of nitrous acid, and alſo ſeparated by one part of copper, and one of the calcined ore of cobalt, in the ſame quantity of the ſame acid; then the whole of the ſolution of iron was mixed with five parts of the ſolution of copper, whence a green and ſaturated nickel colour was formed, which, however, upon the addition of three parts of the ſolution of cobalt, was evidently obſcured: the alkaline lixivium was dropped into this, by which at firſt a ferruginous brown ſediment fell, the ſolution ſtill remaining green; but afterwards all the blue was precipitated, by which at firſt all colour was deſtroyed; but afterwards a red appeared, occaſioned by the cobalt diſſolved in the alkaline ſalt. The ſediment, when reduced, yielded a regulus ſimilar to copper, and ductile, which tinged both glaſs and nitrous acid of a blue colour.

If a ſaturated ſolution of nickel be mixed with half its quantity of ſolution of cobalt, the green colour is much obſcured; but four parts of the former, upon the addition of three of the latter, put off all appearances of nickel.

§ XIV. *Properties of depurated Nickel.*

I have not been able to determine accurately what are the properties of nickel when perfectly pure, as the perpetual preſence of iron

iron in ſome reſpect obſcures its properties.

(A) The ſpecific gravity cannot be aſcertained, eſpecially as the quantity of iron is unknown. Let us ſuppoſe that the pureſt nickel we can obtain, contains of iron a weight = p, and of real nickel = q; as alſo that the ſpecific gravity of the former ingredient is f, of the latter n, and of the mixture a; then, from the known laws of hydroſtatics $\frac{aqf}{pf + qf - ap}$. Now it appears by experiment, that the weight of iron is more increaſed by calcination than that of any other metal, even to 0,36: ſince then the calx of purified nickel increaſes $\frac{1}{9}$ (§ IV. G), if one half be aſcribed to the nickel, as much muſt neceſſarily belong to the iron: beſides, let $\frac{1}{2}$ the increment be ſubtracted, as owing to the charcoal-duſt, nevertheleſs the reſiduum ſhews that more than $\frac{1}{3}$ conſiſts of iron. Let therefore p = 1, f = 8,000, a = 9,000 (§ VII. B), q will be = 2, and n = 9,600. The data of this calculation were ſo taken, that the value of n ſhould come out leſs than the truth; for the increment of the nickel is put equal to that of the iron, which is hardly probable; then the quantity of iron is eſtimated only at $\frac{1}{4}$, although it is certainly greater; and finally, $\frac{1}{4}$ of the increment is aſcribed to the charcoal-duſt, although other experiments ſhew that it adds little or nothing to the weight; hence therefore we conclude, that the true ſpecific

ſpecific gravity of nickel is not leſs than 9,000 at leaſt. The calculation indeed ſuppoſes that the bulk remains unchanged in the mixture, which is a thing that rarely happens; but the error thence ariſing never exceeds 0,7, ſo far as is yet known, and perhaps, in the preſent caſe, is rather to be added than ſubtracted.

If a ſmall portion of gold entered the compoſition, the greatneſs of the weight might thence be explained; but although this metal is almoſt always abſent, as we have before obſerved (§ v. G), yet thirty-ſix parts of it, forty-eight of iron, and one of copper, were formed by fuſion into a globule, the ſpecific gravity of which was 8,8571, but was little ſoluble in nitrous acid; yet, after lying two hours in the menſtruum, the gold was to be ſeen plainly, and with volatile alkali, the menſtruum yielded nothing but a ferruginous brown precipitate, which in the fire put on the appearance of roaſted iron; in all which particulars it differs from nickel.

(B) The ſolutions of nickel in all the acids are of a green colour. The vitriolic acid takes up the calx, and forms a green decaedral ſalt, of an aluminous compreſſed figure, the two oppoſite apices truncated; this acid ſcarcely attacked the regulus but by evaporation to dryneſs. The nitrous acid, by the aſſiſtance of heat, diſſolves both the calx and the regulus, and forms blueiſh-green

green cryſtals, ſpathoſe and deliqueſcent. The marine acid diſſolves both the regulus and the calx, but ſlowly, and not without the aſſiſtance of heat. Both nitrated and ſalited nickel, when freſh, deliqueſce; but by long continuance in a free and warm air, gradually loſe their acid, ſo that at length a green calx of nickel, mixed with iron and arſenic, remains behind. Acid of arſenic, with the calx of nickel, concretes into a green ſaline maſs; but with the regulus it ſeparates a ſaline powder difficult of ſolution. The fluor acid forms with calx of nickel (which it does not eaſily diſſolve) cryſtals of a dilute green. The acid of borax ſcarce diſſolves nickel directly, but takes it up by means of a double elective attraction. Vinegar forms with the calx ſpathoſe cryſtals of an intenſely green colour: it is ſcarcely diſſolved by acid of tartar, at leaſt this menſtruum is not tinged by it. Acid of ſugar changes both the regulus and the calx to a white powder, not eaſily ſoluble in water. The acid of phoſphorus has but little attraction for the calx of nickel, with which it does not form cryſtals, nay the ſolution is ſcarcely green. The acid of ants, by decoction or long digeſtion, attacks the newly-precipitated calx; for the ſolution is green, and upon evaporation yields cryſtals of a deep green colour; theſe are hemiſpherical, formed of filaments diverging from a center, and pellucid; they

reject

reject ſpirit of wine, and are ſcarcely ſoluble in water, unleſs it be ſharpened by an acid. Lemon-juice does not ſeem to act at all upon nickel.

All the acids are tinged of a very deep colour, and this property of nickel is extremely powerful; for the firſt regulus (D), as well as that which is highly depurated, occaſions theſe tinges. This great richneſs of colour agrees well with the idea of a large quantity of matter in a ſmall bulk.

Volatile alkali diſſolves nickel, and the ſolution is blue; the fixed alkali diſſolves very ſparingly, and forms a yellow ſolution.

(C) In proportion as nickel is more pure, it is the more difficult of fuſion, ſo that when at its great degree of purity it requires for fuſion nearly as great a degree of heat as forged iron: it is eaſily fuſed with other metals, but its ſcarcity has prevented us from examining the phenomena ariſing from hence. In general, however, we may remark, that the impure regulus cannot unite with ſilver: this muſt be attributed to the cobalt which it contains; for when well freed from that metal, it eaſily unites in equal proportions with the ſilver, and that without any remarkable diminution either of whiteneſs or ductility. This mixture, fuſed with borax, tinges it of an hyacinthine colour. Copper unites more ſlowly with

with depurated nickel, yielding a red and ductile metallic maſs, which tinges borax of a reddiſh hyacinthine colour. With an equal or even a greater bulk of tin, nothing is produced but a brittle maſs; in which reſpect alſo nickel differs from cobalt. It could not be amalgamated with mercury by trituration. Depurated nickel melts with tin, and forms a brittle compound.

It may ſeem doubtful, whether nickel is to be enumerated among the ductile or the brittle metals. Iron, when fuſed, is almoſt always brittle, ſo that its ductility, when united with nickel, is very remarkable.

(D) Depurated nickel is with great difficulty calcined in the ordinary way in the aſſay-furnace, and aſſumes only a brown colour; but by means of nitre it is more compleatly dephlogiſticated, and becomes green. The metallic calx, vitrified with borax, produces an hyacinthine tinge, which yet, if occaſioned by a regulus not well depurated, vaniſhes on continuing the fire, the glaſs remaining being altogether colourleſs, and upon the addition of nitre only a ſlight blue tinge is produced. A calx of well-depurated regulus of nickel forms a permanent colour. The calx of nickel communicates alſo to microcoſmic ſalt an hyacinthine colour, which, by long-continued fuſion on charcoal, may indeed be weakened, but hardly entirely diſcharged: this colour, on the

the addition of nitre, changes to a violet, and on increaſing the quantity of microcoſmic ſalt, becomes again hyacinthine. If the calx of nickel be added to ſaturation, the fuſed glaſs appears of a blood colour, but upon cooling grows more and more yellow.

DISSERTATION XXI.

OF

ARSENIC.

§ 1. *Historical Introduction.*

ARSENIC is found in the bowels of the earth, either in a metallic form or calcined, or finally, intimately, and in the way of solution, united with sulphur; this diversity could not escape the first discoverers, and hence their opinions concerning its true nature were strangely contradictory for a long time.

We are entirely ignorant at what time it began to be distinguished from other minerals, and when it received the name which it still continues to bear. It is extremely probable that this substance was first discovered by those who wrought in the roasting and fusing of ores, betraying itself by its white

white ſmoak, its garlic ſmell, and its pernicious effects in depraving metals and deſtroying animal life. Ariſtotle mentions the Σανδαραχη; and his diſciple Theophraſtus Ereſius ſpeaks of Αρρενικος, which was called Αρσενικος by Dioſcorides and others, who lived about the beginning of the Chriſtian æra. But theſe denominations comprehended only thoſe minerals which by Pliny, and other Latin authors, are called ſandarach and orpiment. Avicenna, a chemiſt of the eleventh century, who, ſo far as we know, was the firſt who diſtributed minerals into ſtones, metals, ſalts, and ſulphurs, not only ſpeaks of white arſenic, but, what is remarkable, of its ſublimate. Theophraſtus is the laſt who mentions the regulus, although he had before referred ſandarach and orpiment to the metallic ſtones. It is unknown who firſt reduced white arſenic to a metallic form. Paracelſus, in his Manual, aſſerts that arſenic, ſublimed with lime of egg-ſhells, becomes like ſilver; and in the year 1675, Lemeri deſcribed a method of ſubliming arſenic with fixed alkali and ſoap; but in the year 1649, J. Schroder mentions the regulus eliquated from arſenic or orpiment by means of white flux, charcoal-duſt, and iron: he quotes Cloſſæus, but does not give the title of the work. In the Pharmacopœia 1644, this proceſs is not to be found.

Avicenna, and many after him, even to our times, place arſenic among the ſulphurs: Albertus Magnus and others, among the ſaline bodies: Beecher conſiders it as a ſoap, or a ſaline ſulphureous body. Indeed, as white arſenic is ſoluble in water, it is plain that it contains ſomething ſaline, although no appearance of ſuch a thing can be diſcovered either in the regulus alone or in its mineralized ſtate. That this ſaline ſubſtance is of an acid nature, plainly appears from its ready union with alkalis, eſpecially as the celebrated Macquer's experiments ſhew, that neutral cryſtallizable ſalts may be generated from thence; but until our countryman Mr. Scheele's time, no one had been able to extract this acid in its pure ſtate, and the ingenious inventor has lately deſcribed the method he purſued.

As to the ſulphureous nature of arſenic, which ſome perſons ſtrenuouſly inſiſt upon, it muſt be confeſſed that the regulus itſelf, nay even orpiment and realgar, are inflammable; a circumſtance which however does not take place with reſpect to white arſenic. If therefore the ſulphureous quality is to be determined from a ſingle property (in the ſame way as the ſaline) it appears that it is only competent to arſenic in a certain ſtate. But beſides arſenic, zinc and ſeveral other bodies, which are eaſily inflammable, are not however from thence to be denominated ſulphureous,

phureous, unlefs we will confine that appellation to the quantity and connexion of phlogifton adapted to inflammation.

It is commonly faid that arfenic mineralizes metals, and therefore it is confidered as a fulphur by fome, who yet extend the idea of mineralization fo far, as under it to comprehend all mixtures, whereof a metal forms a part: but if we examine this fignification a little more accurately, we fhall eafily fee that it is extended too far; for if this be admitted, we muft at the fame time allow that no native metal is to be found; thus the gold, which is called native, is fcarce ever perfectly pure, but is mixed more or lefs with filver or copper. In the fame way filver is mixed with gold or copper; platina with iron; copper with gold, filver, or iron; nickel with cobalt, &c. If therefore arfenic, which, unlefs in its reguline ftate, never diffolves other metals (§ VI. A), be confidered as a mineralizing fubftance, what hinders us from faying that gold is mineralized by filver and copper, and in general every metal mineralized by another? Beyond doubt, the fame reafon holds good in all. With much lefs appearance of truth can we fay, that metals are mineralized by earths, as thefe latter are fcarce ever, except mechanically, mixed with the ores.

It is much more conformable to reafon and experience, to call thofe metals mineralized which are diſſolved, and actually concealed by a menſtruum. Sulphur is the chief agent employed by nature for this purpoſe; and although the acids of vitriol, of nitre, of phoſphorus, and ſometimes even the aerial acid, occaſion the metals to put on an appearance foreign to their nature, yet the number of theſe is ſo ſmall, that, compared with the ſulphurated minerals, they almoſt vaniſh.

But the idea of a mineralizing arſenic, perhaps, is to be ſought for further. This mineral, ſo troubleſome to the mineralogiſt, occaſioned the alchemiſts to ſuſpect the exiſtence of a certain arſenical principle indiſpenſably neceſſary to the perfection of every metal; a ſuſpicion occaſioned by their ſtrenuous endeavours, during the proceſs of their great work, to diſcover, by the moſt ſubtile ratiocinations, the true compoſition of metals. Even ſo late as the year 1773, the Royal Academy of Sciences at Berlin propoſed the following problem: *Quid arſenico in mineris præſente efficiat natura? Num idoneis evinci queat experimentis quod metalla re vera perficiat? Et ſi ita, quomodo & quouſque hoc fiat?* The premium was adjudged to the anſwer of the celebrated Monnet, in which he, with great ingenuity and truth, conſiders arſenic as a ſemi-metal differing from all others; which is ſo far from conſtituting an eſſential part of the texture of metals, that it unqueſtionably is often totally abſent,

abſent, and when preſent, is always attended by inconveniencies, either carrying it off in its departure, or ſpoiling the maſs. Certainly good copper is, though not without difficulty, eliquated from the grey ore; and ſilver, equally perfect, is obtained from the vitreous as from the red ore. No one as yet has been able to perfect any metal by means of arſenic, and if it be accidentally found mixed with others, it no more contributes to their goodneſs, than the lead in galena is uſeful to the ſilver, or the ſilver to the lead. If recourſe be had to an arſenical principle ſo ſubtile as to evade the obſervation of our ſenſes, let us leave that ſubject to be diſcuſſed by its authors.

All theſe conſiderations, however juſt, do not prevent us from aſſerting, that the acid of arſenic, like other acids, is a mineralizing ſubſtance, when at any time, in a diſengaged ſtate, it meets with a metal in the bowels of the earth, and in that form unites with it.

Among the chemiſts who have laboured during this century to diſcover the properties of arſenic, the celebrated Brandt muſt not be omitted, he being either the firſt who obſerved many of them, or at leaſt the moſt accurate in their deſcription. Mr. Pott has publiſhed a learned treatiſe on orpiment; J. G. Lehman, another on the ſandarach of the ancients; and many other books there are upon the ſame ſubject.

§ II. *Reguline Arſenic.*

Arſenic is found in a metallic form, in Bohemia, Hungary, Saxony, Hercynia, and elſewhere, but particularly at St. Marieaux mines in Alſatia, where not long ſince many hundreds of it were extracted. In Germany it is called Schoerbencobolt, and frequently Fliegenſtein or Muckenpulver, but for what reaſon I know not, as it is not ſoluble in water, and therefore, unleſs when dephlogiſticated, is not at all proper for the purpoſe alluded to by the name; perhaps by ſpontaneous calcination it becomes ſo much dephlogiſticated as to acquire a degree of ſolubility.

As to its form, it is often found ſhapeleſs, friable, and powdery, but ſometimes compact, divided into thick convex lamellæ, with a needle-formed or micaceous ſurface. It admits of a poliſh, which yet is ſoon loſt in the air.

When freſh broken, it appears compoſed of ſmall needle-like grains, with a leaden colour, which yet ſoon grows yellow, and by degrees blackiſh: in hardneſs it ſeems to exceed copper, in brittleneſs to equal antimony.

A regulus

A regulus may alſo artificially be procured from white arſenic, either by ſubliming it with oil, black flux, or other phlogiſtic additaments; or fuſing it with double its weight of ſoap and pot-aſhes; or, finally, precipitating it by ſome other metal from orpiment or ſandarach, fuſed with ſulphur and fixed alkali. That which is obtained by the firſt of theſe methods has a cryſtalline form, more or leſs regular, octaedral, pyramidal, or even priſmatic. Sometimes the artificial regulus is ſold in thick cakes; its ſpecific gravity is 8,310, and therefore a cubic inch weighs about 43,19 drachms avoirdupois.

The mineral commonly called miſpickel, is juſtly reckoned a regulus, as, when totally deprived of ſulphur, it conſiſts of arſenic and iron united in a metallic form; and although the latter amounts to $\frac{1}{2}$, or ſometimes even to $\frac{2}{3}$, yet the compound is not magnetic: this, when ignited, ſends forth an arſenical ſmell, and is thus ſoon rendered magnetic, although the operation be performed on a tile, without any phlogiſton: it eaſily flows in the fire, and in cloſe veſſels the greater part of the regulus of arſenic riſes, leaving the iron at the bottom; a compound of this kind may alſo be artificially made.

Reguline arſenic is far more volatile, and loſes its phlogiſton more eaſily, than any other metal, and therefore it cannot be fuſed,

fuſed, as for that purpoſe a greater degree of heat is neceſſary than what is ſufficient to calcine, volatilize, and inflame it. In open veſſels it begins to ſend forth a viſible ſmoke, in a degree of heat = 180° of the Swediſh thermometer: in order to inflame it, the regulus muſt be dropped into a veſſel of a proper degree of heat, for if the heat be gradually increaſed, the metal is volatilized; the neceſſary degree muſt therefore be inſtantaneouſly applied. The flame is of an obſcure whitiſh blue, diffuſing a white ſmoke, and a garlic ſmell; in cloſe veſſels it retains its metallic nature, and expoſed to the fire is ſublimed in a determinate figure.

§ III. *Habits of Reguline Arſenic mixed in the Via Sicca with other Subſtances.*

(A) Arſenic in a reguline form, added to metals in fuſion, melts with many of them, but thereby thoſe which were malleable become brittle: ſuch of them as flow with difficulty when alone, become more fuſible by means of arſenic; but thoſe which ſoon liquefy (at leaſt tin) become more refractory: thoſe which are yellow or reddiſh are made whiter, according to the quantity of arſenic; and ſuch as are white acquire a grey colour, tin excepted, which by this means acquires a permanent and ſhining whiteneſs, and

and by fusion is able to retain $\frac{1}{2}$ its own weight; nor does it spoil the colour of platina when united with it. Gold fused in a close vessel takes up scarcely $\frac{1}{60}$, silver $\frac{1}{4}$, lead $\frac{1}{6}$, copper $\frac{5}{6}$, and iron more than its own weight. Iron, by means of a large quantity of this metal, loses its magnetic power, but it is difficult to determine exactly how much is sufficient for this purpose (as some of the iron always enters the scoria); but unboubtedly less than an equal quantity is sufficient. Bismuth retains about $\frac{1}{15}$, zinc $\frac{1}{5}$, regulus of antimony $\frac{1}{8}$, and manganese an equal quantity. Nickel and cobalt receive some arsenic, and that not a little; but the quantity can hardly be determined, as these metals are scarce ever got pure. Regulus of arsenic, in a sufficient degree of heat, and by triture of several hours, actually takes up $\frac{1}{6}$ of its own weight of mercury, and forms a grey amalgam.

By means of heat in an open vessel the arsenic may be again expelled, but flying off it generally carries with it some of the metal with which it is united, gold and silver not excepted, if the degree of heat be great and suddenly applied; yet platina perfectly resists the volatilization, nay, being very difficult of fusion, it even retains a portion of the arsenic.

(B) Regulus of arsenic cannot be united by fusion with alkaline salts until the phlogiston is sufficiently diminished; if, there-

fore,

fore, the regulus be added to nitre in fuſion, after detonation they both eaſily unite, and the compound comes out exactly ſimilar to that made with white arſenic (§ VI. B).

(C) Regulus of arſenic, expoſed to diſtillation with the dry acid of arſenic (§ V.), ſublimes before it can be acted upon by the acid, which muſt be firſt melted; but the regulus, when put into the acid in fuſion, ſoon takes fire, and ſends forth a white ſmoke; for the acid, being deprived of its phlogiſton in this inſtance, ſeparates that principle from the regulus, and takes it to itſelf in ſuch quantity as to regenerate white arſenic; and on the other hand, the regulus, by means of the fire, is ſo far ſpoiled of its phlogiſton, as to appear in the form of a calx.

(D) This regulus, in diſtillation with corroſive ſublimate, yields a ſmoking butter, with a ſmall quantity of mercurius dulcis and quickſilver. In this caſe the principles are changed; by means of a double elective attraction, the regulus of arſenic yields its phlogiſton to the baſe of the corroſive ſublimate, which being thereby really calcined, is reduced into perfect mercury, while the marine acid takes up the calx of the arſenic.

(E) Sulphur eaſily diſſolves the regulus; and by fuſion and ſublimation yields yellow or red compounds, according to the different proportion (§ X. B). Hepar ſulphuris

phuris takes up the regulus; but this laſt adheres to it ſo looſely, that it is precipitated by every other metal which can unite with the hepar.

§ IV. *Habits of Regulus of Arſenic, united by the Via humida with other Subſtances.*

(A) Water alone has no effect in this caſe.

(B) Vitriolic acid does not attack the regulus, unleſs concentrated and aſſiſted by fire. The inflammable part of the regulus phlogiſticating the acid flies off, ſo that the remaining part aſſumes the nature of white arſenic, and with menſtrua exhibits the ſame properties as any other metallic calx.

The ſame is true of nitrous acid, except that it attracts the phlogiſton more vehemently.

Marine acid has ſcarcely any effect, unleſs when boiling.

Acid of arſenic, which ſhall be ſpoken of hereafter (§ V.), by digeſtion changes the regulus into a white calx, and is itſelf altogether changed (by means of the phlogiſton which it has taken) into a calx, provided the phlogiſton be in due quantity.

The other acids I paſs over, as entirely refuſing to unite ſo long as the reguline form remains; for no metal, except when more or leſs deprived of phlogiſton, can be diſſolved

dissolved in acids. This impediment is very easily removed by the nitrous acid, but very difficultly by marine, as it abounds in phlogiston itself. In this case, therefore, the same compounds are produced with the regulus, as those with white arsenic, described in § VII. C.

It must here be observed, that solutions of the native regulus always yield a Prussian blue with phlogisticated alkali; which evinces the presence of iron.

Besides, it is to be observed, that the regulus plainly precipitates certain metals dissolved in acids, such are gold and platina in aqua regia, and also silver and mercury in vitriolic or nitrous acid. The silver generally appears in beautiful polished spiculæ, like the Arbor Dianæ; but if the arsenic be suffered to stand long in the nitrous solution, but little diluted, the silver spiculæ are again dissolved, the arsenic becoming in the mean time dephlogisticated. Solutions of bismuth and antimony are but obscurely rendered turbid.

Arsenic and iron naturally united, as in the mispickel, may be separated by digestion with marine acid or aqua regia; for the former menstruum in this way only attacks the iron; and the latter, although it can dissolve both, yet is not able to touch the arsenic so long as any iron remains. In order, however, that all the arsenic may remain alone at the bottom, a very subtile pulverization is neceſſary, together with a juſt quantity and ſtrength of the menſtruum, and heat muſt alſo be carefully avoided.

(C) The alkalis operate more ſlowly in the humid than the dry method, as, before a real union takes place, the phlogiſton muſt be diminiſhed. A ſaline hepar, by boiling, attacks the pulverized regulus; for that which is precipitated by an acid, yields by ſublimation a true orpiment.

(D) The fatty oils, when boiling, diſſolve the regulus, and form a black maſs of the conſiſtence of a plaſter.

§ V. *Calcined Arſenic.*

The regulus, with a very gentle heat, loſes ſo much of its phlogiſton that it flies off in a white ſmoke; yet all the metallic calxes retain much of their inflammable principle, although not ſufficient to give them a metallic appearance. The following experiments will plainly ſhew, that this is true alſo of arſenic:—Let calcined arſenic, moiſtened with nitrous acid, be expoſed to heat, and a copious red vapour will break forth, which, collected, exceeds the arſenic four or five times in bulk; and, upon examination, is found to be no other than that which by the celebrated Prieſtley is called nitrous air; however, this always abounds in phlogiſton, and ſcarcely contains any thing elſe, except a ſmall portion of nitrous

trous acid, dilated into an elaſtic fluid by the abundance of phlogiſton. In this caſe the inflammable principle can be derived from no other ſource than the arſenic ; and we ſhall ſoon have occaſion to take notice of other proofs.

The native calx of arſenic occurs but ſeldom in Saxony and Bohemia ; but is found copiouſly in thoſe places where the ores of cobalt are roaſted, and is collected in the long and winding wooden tubes uſed in that operation. This ſmoke is found ſo loaded with phlogiſton, that it appears grey; but is ſoon made white by ſublimation, either with or without pot-aſhes. This calx is volatile, but leſs ſo than the ſemi-metal itſelf, for it requires at leaſt a degree of 195°. If in a cloſe veſſel it be raiſed by a fire a little higher, it becomes pellucid like glaſs. In the air its ſurface ſoon contracts a white opacity ; but that which is found cryſtallized in the bowels of the earth, is not ſubject to this change. The ſpecific gravity of white arſenic is 3,706, and that of the glaſs about 5,000.

It ſlowly excites upon the tongue an acid ſubdulcid taſte.

White arſenic is in reality nothing elſe but an acid different from all known acids, and loaded with ſuch a quantity of phlogiſton as is ſufficient to coagulate it. 100 parts of white arſenic contain at leaſt 20 of phlogiſton ; and whatever is capable of ſeparating

parating ſo much, is capable of leaving the acid pure. This acid (which has been examined particularly in another place) is of itſelf fixed, but when made red hot decompoſes the matter of heat, gains phlogiſton from thence, and regenerates white arſenic, which, loaded to ſaturation with phlogiſton, becomes reguline. The dry acid, expoſed to a moiſt air, deliqueſces and falls totally into a limpid liquor, containing ſo much water as is neceſſary to the ſolution of the acid in a moderate temperature, that is $\frac{2}{3}$ of its own weight.

It is highly probable that all the metals are only different acids coagulated by a large quantity of phlogiſton, although the connection of thoſe principles is ſo cloſe that we are hitherto ignorant of the means of ſeparating them. The metallic calxes always contain more or leſs phlogiſton, and moſt of them alſo contain aerial acid, which they take from the ſurrounding air in place of their loſt phlogiſton, and pertinaciouſly retain it; yet ſome calxes ſeem always to be free from that acid, although precipitated by aerated alkali: it is alſo certain that white arſenic is free from it. But this doctrine will be more fully illuſtrated in another place. In the mean time it appears from hence what opinion is to be formed of the ſalts and ſulphurs of metals, although the ideas of the ancients upon this ſubject occaſion much obſcurity.

Hence alſo it appears why earths and metallic calxes fix arſenic. Nickel and cobalt generally abound with arſenic, which cannot be expelled by calcination alone; for when a great part is diſſipated by the force of the fire, the reſt either gradually loſes its phlogiſton and adheres like a fixed acid, or is united by fuſion with the metallic earths; but powder of charcoal being added during the calcination, immediately a large quantity of ſmoke breaks forth, which ſmells like garlic, and is nothing elſe but the arſenical acid reduced by phlogiſton to the form of a calx.

§ VI. *Properties of calcined Arſenic mixed by the Via Sicca with other Subſtances.*

(A) White arſenic fuſes with the ſame metals as the regulus does, but in a manner ſomewhat different: it is true that no calx, as ſuch, can be united with metals; but nevertheleſs the calx of arſenic added to them, when fuſed in a crucible, readily unites with them; but let it be remembered, that it is reduced by the phlogiſton of the fuſed metal; therefore, when the metal is an imperfect one, ſcoriæ alſo ariſe, conſiſting of the calcined part of the metal and white arſenic.

(B) White arſenic injected into fuſed nitre excites a violent intumeſcence and efferveſcence, but without any ſcintillation; if this addition be continued until a new portion excites no motion, and the maſs be then well fuſed, the product is called arſenic fixed by nitre. During this operation the nitrous acid is volatilized by the phlogiſton of the metallic calx, and the arſenical acid, being diſengaged, unites with the baſe of the nitre; however, cryſtals are not obtained, becauſe by means of the vehemence of the fire the alkali is ſuperabundant; but by a juſt proportion of alkali and a due degree of heat cryſtals may be produced; for the vegetable alkali requires a ſlight ſuperabundance of arſenical acid in order to produce cryſtals; this neceſſary ſuperabundance may alſo be preſerved in a crucible, provided the fire be ſo regulated that the bottom may be ſcarcely red; it ſucceeds better however in diſtillation.

The reſidua of the diſtillations, performed with an equal portion of priſmatic, cubic, or flaming nitre, all yield arſenicated alkali, which, after ſolution in water, may be cryſtallized. It is vulgarly ſuppoſed that theſe cryſtals cannot be decompoſed by other acids, but erroneouſly. It is evident that though upon the addition of another acid the alkaline baſe unites with it, yet the acid of arſenic, being itſelf ſoluble, will yield no precipitation, nor even occaſion a turbidneſs; from the want of turbidneſs nothing as yet has been eſtimated but the coheſive force of the compound: but the error ariſes from hence, that chemiſts have ſuppoſed that white arſenic enters thoſe ſalts, when in reality it is only the acid. Therefore, in order the more clearly to diſcern the event, we ſhould diſſolve the arſenicated vegetable alkali (the neutral arſenical ſalt of Mr. Macquer) in vitriolic acid; this being done, let the neutral ſalt be precipitated with highly-rectified ſpirit of wine, and waſhed, which is very eaſily done, for the vitriolated vegetable alkali is not at all, and the arſenicated vegetable alkali, but very ſparingly, ſoluble in this ſpirit. The ſalt ſeparated in this manner from the diſengaged acid is ſoon diſtinguiſhable, and in this inſtance exhibits all the properties of vitriolated vegetable alkali: this, therefore, is undoubtedly a decompoſition of the arſenical ſalt by way of ſolution; here the alkali has no effect, as it is itſelf unable to precipitate. But the nature of theſe ſalts will elſewhere bemore accurately examined.

The digeſtive ſalt, common ſalt, and ſal ammoniac, are not changed by arſenic; the reaſon of which undoubtedly is, that the marine acid is naturally loaded with phlogiſton.

(c) Corroſive ſublimate, diſtilled with white arſenic, aſcends unchanged, whatever proportions be employed. Mr. Pott long ſince obſerved, that in this caſe no butter of arſenic ariſes; and certainly no ſuch can ariſe, as the calx of arſenic attracts the marine acid with leſs force than the calx of the mercury does. Let butter of arſenic mixed with calx of mercury be expoſed to diſtillation; at firſt, before the whole can be decompoſed, a little of the butter is elevated, but ſoon after a corroſive ſublimate riſes, and finally a white arſenic.

(D) Fixed alkali with white arſenic melts in the fire almoſt in the ſame way as nitre, only the phlogiſton flies off more ſlowly. Cauſtic vegetable alkali, ignited in a cloſe veſſel, fixes about double its quantity of white arſenic; but the mineral alkali fixes nearly triple. Cauſtic volatile alkali, drawn from white arſenic to dryneſs two or three times repeatedly, becomes at length ſo cloſely united to it that the maſs bears fuſion by means of fire.

Terra ponderoſa and calcareous earth, ſpoiled of the aerial acid by roaſting, retain, on ignition in cloſe veſſels, about an equal quantity of arſenic; but magneſia, pure clay, and ſiliceous earth, ſcarcely any.

(E) Sulphur eaſily unites with white arſenic, reduces and mineralizes it; hence this compound always diffuſes a moſt penetrating odour of volatile vitriolic acid; for a portion of the ſulphur yields to the calx of the arſenic a great quantity of phlogiſton. See alſo § VIII. IX. and X.

Saline hepar alſo diſſolves white arſenic, but more readily attacks the regulus.

Equal quantities of ſulphur, crude arſenic, and white arſenic, unite by fuſion in a cloſe veſſel, and generate the *lapis de tribus*, which is alſo called pyrmiſon or arſenical magnet; this is red and ſometimes tranſparent.

§ VII. *Properties of calcined Arſenic mixed by Solution with other Subſtances.*

(A) 80 parts of diſtilled water, in an heat of 15°, diſſolve one of white arſenic, and when boiling 15 parts of water are ſufficient. But the arſenic, when once diſſolved, is more eaſily retained than taken up; ſo that in a moderate heat 15 parts can hold one ſuſpended a long time; the ſame is true of the other ſolutions. Solution of arſenic changes the deep tincture of turnſole to a red colour, but, like other metallic ſolutions, makes ſyrup of violets green; it is not changed by neutral ſalts, but is precipitated by moſt metallic ſalts, and that in ſuch a way that the metallic calxes, united with the arſenic, fall (though ſlowly) to the bottom.

It may be aſked, whether the whole of the arſenic, or only the arſenical acid, unites with the metallic calx, yielding the phlogiſton to the menſtruum of the other metal? Certainly ſuch a mutual commutation of principles does not appear improbable, if we conſider only thoſe caſes in which the menſtruum is vitriolic or nitrous acid; but as iron (for example) united with marine acid (which does not attract the phlogiſton of white

white arſenic) as well as when it is joined to nitrous acid, is precipitated, it would appear that the whole of the arſenic is united, at leaſt in certain caſes, to the metallic calxes.

(B) 70 or 80 parts of ſpirit of wine, by means of a boiling heat, diſſolve one of arſenic.

(C) Concentrated vitriolic acid, boiled with white arſenic, diſſolves a ſmall portion of it, which yet upon cooling it again depoſits in the form of cryſtalline grains: this vitriol diſſolves in water with much greater difficulty than white arſenic itſelf; expoſed to the flame of a blow-pipe, it ſoon emits a white ſmoke, but at the ſame time is formed by fuſion into a globule, which at firſt bubbles, but ſoon grows quiet, and although of a white heat is but ſlowly conſumed: the white arſenic quickly flies off, not being capable of enduring fuſion, and much leſs ignition.

If the affuſed acid be evaporated to dryneſs, the repetition of this operation fixes the arſenic more and more, by carrying off the phlogiſton, but ſcarcely exhibits the arſenical acid pure.

The ſame thing happens with the nitrous acid; when diluted it diſſolves the calx, which on cryſtallization appears nearly under the form of white arſenic, but in its nature is a true middle metallic ſalt, which is difficultly ſoluble in water, and expoſed to flame upon charcoal exhibits the ſame phænomena na with thoſe exhibited by the vitriol of arſenic above mentioned, but is conſumed ſomewhat more quickly.

Concentrated nitrous acid deprives the calx of its phlogiſton more effectually; and by a proper quantity, if evaporated to dryneſs, the calx may be brought to ſuch a ſtate that the acid alone ſhall remain. That ſubſtance which is commonly called gum of arſenic, is nothing but arſenic more or leſs dephlogiſticated, but always more ſo than white arſenic.

The marine acid contains phlogiſton as one of its principles, it therefore attacks white arſenic in a different way: when concentrated and boiling it diſſolves $\frac{1}{3}$ its own weight, of which no ſmall portion again ſpontaneouſly ſeparates upon cooling, but is ſaturated with marine acid. This ſalt, which may alſo be had in a cryſtalline form, is much more volatile than the former, nor does it by any means endure ignition; in a cloſe veſſel it all readily ſublimes, and is ſparingly ſoluble in boiling water (§ IX. D.). This ſolution is of a fine yellow, and ſcarcely differs from butter of arſenic except in its degree of concentration. The very nature of marine acid prevents the acid of arſenic from being diſengaged by its means; which yet is eaſily made to appear, if to a ſolution of white arſenic in boiling marine acid, be added double the weight of nitrous acid; the liquor being then evaporated

rated to dryneſs, the arſenical acid will remain, which, in order to free it from any foreign acid, ſhould be urged by fire until it begins to be ignited: by this method 100 parts of white arſenic yield about 80 of dry acid. In this operation the nitrous acid acts more readily upon the phlogiſton of the white arſenic than when it is poured on the powdered arſenic; as in the former caſe the ſolution effects a more perfect diviſion of the arſenic: hence it alſo appears why white arſenic is diſſolved in greater quantity, and without any ſubſequent cryſtallization, by aqua regia than by any other acid.

The phlogiſticated alkali precipitates metals diſſolved in acids, yet leaves arſenic nearly untouched, both in vitriolic and nitrous acids, and in aqua regia; which happens either from the ſmall quantity of the matter diſſolved, or from its nature being changed. From the marine acid it ſeparates arſenic of a white colour: in this caſe error is carefully to be avoided, for the ſolution may be precipitated by water alone, unleſs the quantity of marine acid be large; beſides, the diſengaged alkali, which is frequently found in this lixivium, muſt be ſaturated by the acid.

Marine acid is dephlogiſticated by digeſtion with manganeſe, and is reſolved into a red vapour, which in a cloſe veſſel ſpoils a certain quantity of white arſenic, diſſolved in water, of its inflammable principle, ſo that the

the veſſel is found to contain ſeparately water, acid of arſenic, and marine acid regenerated; the firſt of theſe may be obtained alone by evaporation to dryneſs.

The power of the other acids upon arſenic has not yet been ſufficiently examined. The acids of arſenic and of fluor diſſolve it, and form cryſtalline grains; and that ſedative ſalt has the ſame effect I hardly entertain a doubt; although it muſt be confeſſed that borax, which is ſaturated with that acid, does not precipitate arſenic diſſolved in water. The acid of ſugar eaſily takes up white arſenic, and yields priſmatic cryſtals; the ſame is nearly true of the acid of tartar: vinegar, and the acids of ants and of phoſphorus, alſo attack it, and yield cryſtalline grains, which are ſcarcely ſoluble in water, nor have they yet been found to contract any union with that fluid in the way of deliqueſcence.

From what has been ſaid it appears plainly, that ſolutions of arſenic made in acids, in certain caſes depart from their uſual nature; which we have already ſhewn to be owing to the adherence of the phlogiſton being ſo looſe that the acid of arſenic is readily ſet at liberty.

(D) The fixed alkalis diſſolved in water take up white arſenic; and if by means of heat they be loaded with it, a brown tenacious maſs is produced, which acquires ſolidity, is of a diſagreeable ſmell, and is called

hepar

hepar arſenici. The arſenic is partly precipitated by mineral acids, though a portion of it gradually loſes its phlogiſton and adheres more tenaciouſly.

A ſolution made with volatile alkali ſeems to effect this decompoſition more readily, as no precipitation is occaſioned in it by acids.

(E) A limpid ſolution of ſaline hepar, dropped gently into a ſolution of white arſenic, floats, forming upon the ſurface a grey ſtratum, which at length diſturbs the whole of the liquor.

(F) White arſenic, diſſolved in water by the aſſiſtance of heat, attacks ſome metals, particularly copper, iron, and zinc, nay the two laſt ſolutions yield cryſtals by evaporation. Theſe compounds are not viſibly changed either by acid or alkaline ſubſtances. Volatile alkali does not diſcover the copper by a blue colour, nor in the martial ſolution does phlogiſticated alkali occaſion any blue ſediment. The cauſe of theſe phænomena is to be ſought for in the ſuperabundance of phlogiſton: for the acid of arſenic takes up all metals; united with copper it is diſſolved by the volatile alkali with a blue colour, and joined with iron it exhibits Pruſſian blue in the uſual way: the phlogiſton which coagulates the acid into white arſenic, is the ſubſtance which in theſe mixtures conſtitutes the only material difference.

§ VIII.

§ VIII. *Mineralized Arſenic.*

We have already obſerved that arſenic, both reguline and calcined, may be united with ſulphur (§ III. VI). Nature ſpontaneouſly produces theſe mineralizations yellow or red, ſometimes pellucid and cryſtalline; the yellow ſeem to affect a lamellated form, the red a priſmatic.

In the roaſted heaps of arſenical ores, there frequently are found beautiful cryſtals, partly tetraedral, partly octaedral, ſome of which are hollow pyramids trigonal or tetragonal, each triangle being compoſed of filaments reſpectively parallel to the ſides: thus an hollow trigonal pyramid, frequently filled up with leſſer pyramids continually decreaſing in ſize, forms a tetraedrum; but 8 tetraedra, properly diſpoſed, form an octaedron. Thus in the via ſicca is formed a ſtructure entirely ſimilar to that which common ſalt, digeſtive ſalt, and perhaps all others, aſſume in the way of ſolution.

Iron at the ſame time entering theſe mineralizations, renders the colour white, together with a poliſhed and metallic appearance. To this claſs belong the ores, which are commonly called white or arſenical pyrites. Arſenic with ſulphurated ſilver forms the red ore of ſilver, and with ſulphurated ſilver and copper, the white or

grey

grey ore of ſilver; it appears to be only mechanically mixed with the cryſtallized ores of tin, and the calcined ores of cobalt.

The ſpecific gravity of orpiment is 5,315, but that of realgar about 3,225.

Orpiment and realgar ſublime totally in a gentle heat, unleſs they be mixed with other ſubſtances; yet they ſuſtain fuſion, and the former of them is thence made red. The arſenical pyrites yields a ſublimate more or leſs white, in proportion to the quantity of ſulphur; but the greater part of it does not ſublime, but remains at the bottom.

§ IX. *Properties of mineralized Arſenic mixed by the Via Sicca with other Subſtances.*

(A) Of thoſe metals which readily unite with ſulphur and arſenic, a certain quantity may be united with orpiment and realgar. We have already mentioned the ſtone called pyrmiſon (§ VI. E), and many other ores of this kind (§ VIII.), which may alſo be artificially imitated. Silver, mineralized by fuſion with orpiment, yields the red ore of ſilver. The reſt may be formed ſtill more eaſily.

(B) Nitre is alkalized by mineralized arſenic, for it detonates partly with the ſulphur, partly with the arſenic, which when mineralized is always found in a form nearly

reguline.

reguline. The alkali thus disengaged, either forms a sal polychrest with the acid of the sulphur, or unites intimately with the arsenic (§ VI. D).

(C) Fixed alkali, added in proper quantity, either to orpiment or realgar, and exposed to a subliming heat, fixes the sulphur, but discharges the greatest part of the arsenic; yet the hepatic mass retains a small quantity of it, and if the alkali abounds, scarce any of the arsenic rises.

(D) Orpiment, on distillation with double or triple its quantity of corrosive sublimate, yields two liquids which refuse to mix; at length, on increasing the heat, a cinnabar arises. In the recipient, a butter of arsenic is found at the bottom, pellucid, of a ferruginous brown, which in the open air at first sends copiously forth a visible white smoke, and attracts the moisture of the atmosphere, by which it is gradually precipitated. The genesis of the butter has been already explained (§ III. D; VI. C); it is very remarkable that it unites with marine acid so slowly, that they seem to repel one another, nor can they be made to unite beyond a certain degree. Distilled water added to the butter precipitates a white powder, which though ever so well washed, retains somewhat of acidity; for a portion of butter of arsenic is yielded on distillation; a circumstance which is also true of Algarotti's powder. The smoke affects the organ of smell

ſmell with a peculiar penetrating odour, ſomewhat reſembling that of phlogiſticated vitriolic acid, and depoſits white flowers.

The ſupernatant liquor, which authors compare to oil, is yellowiſh and pellucid; with water and ſpirit of wine it quickly ſeparates a white arſenical powder; is not diſturbed by the ſtronger acids; with alkalis it effervefces, and is precipitated. If it be kept in a cucurbit with a long neck, and unſtopped, white flowers gradually concrete round the orifice; theſe are lax, and ſometimes approaching to a cryſtalline form. Finally, by ſpontaneous evaporation pellucid cryſtals appear at the bottom of the liquor, which are very difficultly ſoluble in boiling water, but when diſſolved, precipitate ſilver from nitrous acid, and on the addition of an alkali, let fall ſome arſenic. In lime-water a white cloud ſlowly ſurrounds them; expoſed to the fire, they neither decrepitate nor loſe their tranſparency, but totally ſublime without any arſenical ſmell, which yet immediately appears, if ignited phlogiſton comes into contact with them. No traces of mercury appear in this liquor, either by alkali or copper; undoubtedly, if any ſublimate was preſent, it would remain in the water after the precipitation of the arſenic. Terra ponderoſa, diſſolved in marine acid, and dropped into this liquor, does not form even the

ſlighteſt

ſlighteſt congrumation, ſo that there is no vitriolic acid preſent.

From what has been ſaid it appears, that the ſupernatant liquor is no other than a very dilute butter of arſenic, which, on account of the water, contains leſs arſenic. The butter contains the acid in its higheſt degree of concentration, and therefore loaded with a larger quantity of arſenic; the former liquor will therefore be more abundantly obtained, if the mixture of corroſive ſublimate and arſenic be ſet to ſtand a night in a cellar, or moiſtened with water, before it is ſubjected to diſtillation. As the common marine acid can diſſolve only a determinate quantity of the butter, it follows, that what remains after compleat ſaturation ſhould totally refuſe to mix. Marine acid too much diluted precipitates the butter; but in proportion as it is ſtronger, it diſſolves a greater quantity.

§ x. *Properties of mineralized Arſenic mixed by Solution with other Subſtances.*

(A) Water has no effect on mineralized arſenic.

(B) The acids operate according to circumſtances, eſpecially the nitrous acid and aqua regia; the former menſtruum, if concentrated, ſoon deſtroys the red colour of realgar, but does not affect the yellowneſs of of orpiment, for its primary action is to calcine the arſenic, which in realgar muſt neceſſarily change the red colour to a yellow.

Aqua regia, by long digeſtion, takes up the arſenic, but ſo as to leave the ſulphur alone at the bottom; hence we may diſcover the proportion of ſulphur to arſenic. But this operation muſt be ſkilfully performed, leſt on the one hand, by the inertneſs or inſufficient quantity of the menſtruum, ſome part which ſhould be taken away remain untouched; or, on the other, leſt that portion which ſhould remain entire be diminiſhed. The colour of the reſiduum ought to be altogether grey, for ſo long as any yellow particles remain mixed with it, ſome of the arſenic alſo remains. By too much heat, or too long boiling, eſpecially if the nitrous acid be ſtrong, more or leſs of the ſulphur is alſo deſtroyed; for the nitrous acid takes away the principle of inflammability from the vitriolic, ſo as to ſet the latter at liberty.

If iron be preſent in the mineralization, it is all diſſolved in virtue of its ſuperior attraction before the arſenic is acted upon, unleſs it be too much calcined during the operation, either by heat, by the acceſs of air, or by the great power of the menſtruum.

The red ore of ſilver is compleatly decompoſed by aqua fortis, which takes up

 the

the ſilver and the arſenic, ſo that the ſulphur alone remains at the bottom; by this method, 100 parts of the tranſparent cryſtals yield about 60 of ſilver, 27 of arſenic, and 13 of ſulphur; iron is not always preſent.

The white ore of ſilver, firſt treated with aqua fortis, lets fall the ſilver and copper, and then yields the remainder of the arſenic to aqua regia, ſo that at length the ſulphur may be obtained pure: the diſſolved ſilver may be precipitated by copper.

(c) Cauſtic fixed alkali, boiled in water with orpiment, yields a fœtid hepatic ſolution, called by ſome a ſympathetic ink.

Orpiment boiled in water, with double the weight of quick-lime, affords a liquor which may be employed for proving wines; in this caſe the hepar calcis operates. Theſe ſolutions, upon the addition of acids, depoſit both the ſulphur and the arſenic.

(d) Oils too, aſſiſted by heat, diſſolve both orpiment and realgar.

§ xi. *Uſes of Arſenic.*

Concerning the uſes of this metallic ſubſtance, we can only treat in a very ſlight way.

It can hardly be doubted but that it may be applied to valuable purpoſes in medicine, and experiments have long ſince put that matter entirely out of doubt; but with

reſpect

respect both to its dose and preparation, the utmost caution is necessary. From the properties disclosed by the foregoing experiments, it appears that this most virulent of all poisons acts in the manner of an highly corrosive acid, and that even externally (§ v.). Since then phlogiston and alkalis are the most powerful correctors of acid acrimony, it will readily occur how it may be mitigated, and its deleterious effects obviated. Hence too it appears why realgar is less noxious, why the regulus is milder than white arsenic, and this again milder than the dry acid; and why the baths of Carlsbad, which contain a mineral alkali only, united with aerial acid, are extremely useful in diseases occasioned by arsenic: why arsenic, taken internally without the necessary correction, occasions by its irritating quality convulsive motions, among other symptoms, both in the stomach and other parts of the body. To pass over other matters, which from the chemical analysis of arsenic might be useful in the practice of medicine, this only I add, that of all the metals arsenic most easily loses its phlogiston (§ II.); therefore we should be cautious in confiding to phlogistic correctors, as the phlogiston may be separated in the viscera by many different ways. The instance of a man poisoned by arsenic, who was dissected in the anatomical theatre at Upsal, shewed that the penetrating garlic smell may be excited ſimply by a tendency to the putrefactive fermentation.

The pſilothrum turcicum contains orpiment, among other ſubſtances; but its depilatory power is perhaps more properly aſcribed to the cauſtic alkali.

Philoſophers are wont to evince the extraordinary poroſity of bodies, and the wonderful ſubtilty of vapours, by the ſympathetic ink (§ x. c.); for writing made with vinegar of litharge, by itſelf inviſible, expoſed to the vapour of this liquor, becomes in a few minutes of a brown colour, even though a great many folds of paper be interpoſed.

Wines naturally acid, or grown ſo by age, ſtill continue to be edulcorated by lead, notwithſtanding the puniſhments attending the detection of this fraud: it is therefore of great conſequence to be in poſſeſſion of an eaſy method of diſcovering ſuch a ſophiſtication. For this purpoſe the probatory liquor (§ x. c.) is commonly employed; for this, when dropped into pure wine, occaſions nothing but a yellow precipitate, but when the wine is adulterated, a brown or black. This may alſo be done by a ſaline hepar; but fraud and avarice have contrived methods of eluding this proof, unleſs chemiſtry lend its aſſiſtance; for if a ſmall quantity of chalk be contained in the wine, the ſaline hepar fails, for the white calcareous earth falling, diminiſhes the blackneſs.

blacknefs. A large proportion of tartar, renders the probatory liquor ineffective, as the tartareous acid forms with the lime a white falt very difficult of folution.

Arfenic fometimes enters metallic compofitions, efpecially copper and tin; but it is much to be wifhed that fuch compofitions were banifhed, at leaft from the kitchen. Shot made of lead is fometimes hardened by orpiment.

Regulus of arfenic enters into the compofition of Meuder's phofphorus. The power of the calx in vitrification was long fince known to Geber, and therefore it is frequently employed in glafs-houfes, either for facilitating fufion, for acquiring a certain degree of opacity, or, finally, for carrying off phlogifton. The method in which mountain cryftals, placed over orpiment, white arfenic, crude antimony, and fal ammoniac, mixed in a crucible, are tinged by means of heat, is defcribed by Neri, and upon trial this is found to be true; I have thus obtained thefe cryftals beautifully marked with red, yellow, and opal fpots, but at the fame time cracked, which could fcarcely be avoided.

In painting too the artifts fometimes employ arfenic. Painters in oil frequently ufe both orpiment and realgar; and it is probable that wood covered with a pigment mixed with white arfenic, would not be liable to be fpoiled by worms. A moft beautiful green pigment may be precipitated from blue vitriol, by means of white arſenic diſſolved in water, together with vegetable alkali; this, prepared either with water or oil, affords a colour which ſuffers no change in many years. The playthings of children, however, ſhould not be painted with this or any other preparation of arſenic, on account of their cuſtom of putting every thing into their mouths.

DISSERTATION XXII.

OF THE

ORES OF ZINC.

§ 1. *Historical Introduction.*

THE ſemi-metal, which at preſent is called Zinc, was not known ſo much as by name to the ancient Greeks and Arabians. The name which it bears at preſent firſt occurs in Theophraſtus Paracelſus (*a*); but no one as yet has been able to diſcover the origin of this appellation. A. G. Agricola calls it contrefeyn (*b*); Boyle, ſpelt-rum (*c*): by others it is denominated ſpe-auter, and Indian tin (*d*). Albertus Mag-

(*a*) In operibus, paſſim.
(*b*) De re metallica.
(*c*) Ponderab. flammæ.
(*d*) Fœda trifida chymica.

nus, more properly called Bolſtadt, who died in 1280 (*e*), is the firſt who makes expreſs mention of this ſemi-metal. He calls it golden marcaſite, aſſerts that it approaches to a metallic nature, and relates that it is inflammable. However, as zinc is white, the name of golden marcaſite is not very proper; it would therefore appear probable, that it derives that name from the golden colour which it communicates to copper, had not Albertus expreſsly ſaid, that copper united with golden marcaſite becomes white; but he has probably either miſunderſtood or miſrepreſented what he had heard related by others. It may alſo happen that zinc was formerly thought to contain gold. J. Mattheſius, in 1562 mentioned a white and a red zinc (*f*); but the yellowneſs and redneſs are only to be underſtood of the ores. Hollandus, Baſil Valentine, Aldrovandus, Cæſius, Cæſalpinus, Fallopius, and Schroeder, obſerve a profound ſilence on that head (*g*).

The eaſtern Indians have long ſince been in poſſeſſion of the method of extracting pure zinc from the ore, at leaſt, in the courſe of the laſt century. This metal was brought from thence to Europe. Jungius mentions the importation of zinc from In-

(*e*) In libro mineralium.
(*f*) Sarepta.
(*g*) Pott on Zinc.

dia,

dia, in 1647 (*h*): a metal of this kind, under the name of tutenag, is ſtill brought from thence, which muſt be carefully diſtinguiſhed from the compound metal of that name. G. E. van Lohneiſs tells us, in 1617, that a long time before zinc had been collected by fuſion at Goſlar (*i*). It has been long uſual to form orichalum from the ores of zinc by the addition of copper; but it does not yet appear at what time this art was invented. Pliny makes mention of the orichalum, as alſo of three ſpecies of Corinthian vaſes, one of which is yellow, and of the nature of gold (*k*). Eraſmus Ebner of Norimberg, in the year 1550, was the firſt who uſed the cadmia of Goſlar for this purpoſe.

In the year 1721, Henckel indeed mentioned that zinc might be obtained from lapis calaminaris by means of phlogiſton, but he conceals the method (*l*). The celebrated Anton. van Swab. in 1742, extracted it from the ores by diſtillation, at Weſterwick in Dalecarlia (*m*). It was determined to found a work for the purpoſe of extracting larger quantities of this ſemi-metal;

(*h*) De mineralibus.
(*i*) Bericht von Bergvercken.
(*k*) Hiſt. Nat. xxx. c. 2.
(*l*) Pyritologia.
(*m*) Elogium magni hujus metallurgi coram, R. Acad. Stock. recitatum.

but

but afterwards, for various reaſons, this project was laid aſide; therefore the illuſtrious Margraaf, not knowing what had been done by the Swediſh mineralogiſts, in the year 1746 publiſhed a method of performing this operation, which he had diſcovered himſelf (*n*).

It is not known how zinc is extracted in China. A certain Engliſhman, who ſeveral years ago took a voyage to that country for the purpoſe of learning the art, returned ſafely home, indeed, and appears to have been ſufficiently inſtructed in the ſecret, but he carefully concealed it. We find afterwards that a manufactory had been eſtabliſhed at Briſtol, where zinc is ſaid to be obtained by diſtillation per deſcenſum. We have already ſeen that it had been before obtained in Sweden by diſtillation per aſcenſum, which afterwards was effected in larger quantity, by Meſſ. Cronſtedt and Rinman, two very celebrated mineralogiſts and metallurgiſts.

The difficulties occaſioned by the volatile and combuſtible nature of this metal, for a long time retarded the knowledge of the ores containing it; nor is that wonderful, as, being of a metallic form, it has even to our times been conſidered as compoſed of two or three ingredients. Albertus Magnus

(*n*) Mem. de l'Acad. de Berlin.

nus thinks iron an ingredient; Paracelſus called it a ſpurious ſon of copper; Lemery holds it to be a ſpecies of biſmuth; Glauber, and many alchemiſts, conſider it merely as an immature ſolar ſulphur; Homberg, as a mixture of tin and iron; Kunckel, as a coagulated mercury; Schluter, as tin made brittle by ſulphur, &c.

The ore, which reſembles true galena, is called pſeudo galena; and is for that reaſon, perhaps, by the inhabitants, called blende, as in texture and ſplendor it reſembles the blends, though it contains no ſilver. The celebrated Brandt, in 1735, ſhewed that this contained zinc (*o*); and ſoon after D. Swab actually extracted it from the Bolognian pſeudo galena, which poſſeſſes a metallic ſplendor. The Baron Funch, in 1744, determined the preſence of zinc in pſeudo galena from the flame and the flowers (*p*); and in 1746 Mr. Margraaf ſet the matter out of doubt.

Zinc cannot be united with ſulphur alone, yet is found joined with it in the pſeudo galena; and this conjunction Mr. Cronſtedt (*q*) thinks is effected by means of iron; but Mr. Sage (*r*) ſuppoſes that in this inſtance an earthy hepar is formed by means of lime.

(*o*) Act. Upſal.
(*p*) Act. Stockholm.
(*q*) Cronſtedt Mineralog.
(*r*) Mem. de l'Acad. de Paris, 1771.

Julius,

Julius, in the year 1570, undertook, at Rammelsberg, the preparation of a certain salt, which he called Ertz-alaun, but which we now meet with under the name of Gallizenstein. No one, before 1735, knew the true composition of this salt; but about that time D. Brandt published two observations explaining its nature; for he found that this salt calcined, and then treated with charcoal-dust and copper, formed brass; and also that zinc, directly dissolved in vitriolic acid, formed a salt of the same nature as gallizenstein. In the same year Mr. Hellot communicated the latter of these experiments, made by himself, to the Royal Academy at Paris, proving that white vitriol is a middle salt composed of zinc and vitriolic acid.

Mr. Sage has lately attempted the analysis of lapis calaminaris, in which he asserts that zinc is mineralized by marine acid. The same author contends that zinc is found in manganese (*s*); and Dr. Bayen relates that he discovered it in the white ores of iron (*t*): but they have both mistaken manganese for zinc (*u*).

(*s*) Mem. de l'Acad. de Paris, 1770.
(*t*) Journal de Physique, par Mr. Rozier, 1776.
(*u*) See the Treatise on the White Ores of Iron.

§ 11. *Zinc*

§ 11. *Zinc is presented to us by Nature under a Variety of Forms.*

It is not yet certain whether zinc be ever found native, unless we suppose the grey, flexible, metallic, inflammable filaments, surrounded by yellow ochre, which Mr. de Bomare observed in the neighbourhood of Limburg and Rammelsberg, to be produced solely by the hands of nature (*x*). In order to discover their true origin, they must be attentively considered, and their nature solicitously investigated in the matrixes. In the mean time, it will be proper briefly to describe the habitudes of perfect zinc, when exposed to flame upon charcoal. This semi-metal scarcely melts alone by the blow-pipe, as its whole surface is quickly covered with a calcined crust; but the internal mass, fused and exposed to strong heat, now and then explodes with a beautiful greenish blue flame, and disperses a white calx.

A small piece of zinc is taken up with effervescence by microcosmic salt in fusion; at the same time it sends forth many flashes, with a crackling noise; but if the heat be too great it explodes, scattering about ignited particles.

(*x*) De Bomare, Mineralogie.

Borax

Borax takes up zinc with a degree of effervefcence, and the fufed regulus at firft tinges the flame; if the blaft be intermitted it fends forth a flafh, and afterwards it is difficult to reproduce the phænomena; but the regulus is gradually diminifhed, and the mafs of borax fpreads upon the charcoal without any explofion.

The mineral alkali, expofed to heat with zinc, in a filver fpoon, corrodes it, but without any tinged flame, or any explofion (*y*).

The ores containing zinc differ much in appearance and properties; but fo long as the uncertainty of the exiftence of native zinc remains, they may, agreeably to their nature, be divided into two claffes, fome containing the femi-metal fimply deprived of phlogifton, the others holding it mineralized, either by fome acids, or united to fulphur by the means of iron.

Calcined Zinc.

(A) Pure zinc, calcined in difcrete particles, is extremely rare. To this we may refer the zinc brought from China by Grill, and defcribed by Von Engeftrom in the year 1775 (*z*).

(*y*) The Chinefe zinc, upon examination, yields fcarcely half a pound of lead in an hundred. The zinc of Goflar contains fomewhat more; but neither the one nor the other yields the fmalleft particle of iron.

(*z*) Act. Stock. 1775.

That the comparifon with native zinc may be more eafily made, it will be neceffary to defcribe briefly the habitudes of flowers of zinc, as examined by the blow-pipe. Thefe flowers, expofed alone to the flame on charcoal, put on a phofphoric fplendor, which vanifhes when the flame intermits: they alfo remain fixed and refractory.

With microcofmic falt they are readily diffolved without fpumefcence: upon cooling, the globule remains tranfparent, if the zinc amounts to lefs than double the bulk of the falt; if to more, the globule is milky. In proportion as it is more faturated, it adheres the lefs to the charcoal.

With borax the fame thing happens, but the flowers are more flowly taken up; and in proportion as the globule is more loaded, it expands more upon the charcoal.

In a filver fpoon, with mineral alkali, they fuffer no fenfible change.

(B) Calcined zinc, mixed in various proportions with earthy and ferruginous particles, commonly called *lapis calaminaris*, is employed in the compofition of brafs: it is of a ferruginous, yellow, or white colour, and generally hard; but the hardnefs is not the fame in all, nor is it fufficient to ftrike fire with fteel.

Thefe minerals exhibit with the blow-pipe the fame phænomena as the preceding varieties, except thofe which abound in

iron;

iron; for the ſubtile powders of theſe laſt, expoſed to a white heat, are of a more obſcure colour, and are magnetic (*a*). The microcoſmic ſalt contracts with them the colour of ſmoked glaſs; borax a yellowiſh green; but in both caſes, if too much ore be added, an opacity is produced. The mineral alkali grow black.

Mineralized Zinc.

Zinc aſſumes appearances foreign to its nature, in the hands of nature, partly by its union with a certain native acid, partly by means of ſulphur. Among the acids which mineralize zinc, no other are yet known but the aerial and the vitriolic.

Aerated zinc is found concreted ſo hard, as ſometimes to ſtrike fire with ſteel; it exhibits an appearance like quartz, upon breaking, and is on the ſurface generally knotty, ramous, or variouſly contorted into lamellæ: this is called glaſs of zinc. And Mr. von Swab obſerved, during diſtillation, that a matter, exactly of the appearance above deſcribed, was produced through the ſmalleſt cranny in the apparatus.

A variety of this mineral, brought from England, expoſed to flame with the blow-

(*a*) The celebrated Rinman, after calcining the white lapis calaminaris of Aix-la-Chapelle for the ſpace of eleven days, in one of the furnaces uſed for the preparation of ſteel, found that it adhered to the magnet almoſt in the ſame manner as filings of iron.

pipe,

pipe, remained without liquefaction, but cracked, was as it were resolved into flowers, and acquired a more dilute colour. The smell shews no traces of sulphur, nor is it magnetic either before or after calcination. The microcosmic salt, and also borax, dissolve it without difficulty; the latter somewhat more slowly. The mineral alkali scarcely takes up any, so that its habitudes much resemble those of the flowers.

Artificial vitriform zinc manifests the same properties as the natural, but does not split, and is more slowly and sparingly dissolved in the usual salts.

(B) To this class also must be referred the variety which is soluble in water by means of vitriolic acid. Mineralogists very properly enumerate this among the metallic salts; yet it must not be passed over in a place where our intention is to speak of all the minerals which contain zinc abundantly.

Pure vitriol of zinc, exposed to the flame, on fusion foams violently, and, finally, leaves behind a refractory mass, which does not grow phosphoric like the flowers.

This vitriol, calcined, is readily taken up with effervescence by the microcosmic salt: if too much of the vitriol be added, the globule is of an opal colour. The same takes place with borax. It unites at first with mineral alkali, with violent efferves-

 cence;

cence; but afterwards is very little acted upon.

Native vitriol of zinc is ſcarce ever found pure, but mixed with copper or iron, or both; ſo that the phænomena vary in reſpect both of the quantity and quality of the heterogeneous mixture.

Zinc, mineralized by ſulphur, produces various colours. I have known it black, brown, yellow, greeniſh, and, finally, with a metallic ſplendor; which laſt is called by Mr. Cronſtedt, particularly, the ore of zinc. The pſeudo galena puts on a ſquamous form, not unlike that galena which ſhines when the little lamellæ are viewed obliquely. Sometimes it is found ſemi-tranſparent, very rarely octaedral; it occurs accidentally, mixed with ſilver, lead, copper, arſenic, and other metals.

The habitudes vary a little, according to the different heterogeneous matters. For example, we ſhall deſcribe three varieties found in Sweden; *viz.* the black of Dannemer, the red of Sahlberg, and the metallic one of Boval.

The firſt of theſe does not ſtrike fire with ſteel, yields a brown powder which decrepitates upon heating, ſends forth a ſmoke of a ſulphureous ſmell, and depoſits upon the coal partly white flowers (conſiſting of zinc), and partly yellow ones (conſiſting of lead): it is not magnetic, either crude or roaſted: when

when expoſed to the flame, in ſuch a manner that the divided apex of the flame is reflected, it frequently appears tinged with zinc.

The ſecond is little changed by pulverization; it ſtrikes fire with ſteel on account of the quartzoſe matrix; it neither decrepitates nor ſmokes, and generates flowers but ſparingly; yet it ſometimes tinges the flame.

The third produces an aſhen brown powder; does not decrepitate; expoſed to the apex of the flame, it exſudes ſmall drops, and diſperſes flowers.

The microcoſmic ſalt diſſolves the firſt, and at the beginning puts on an opake whiteneſs; but when nearly an equal bulk is added, it grows black. The ſecond is never entirely taken up, for the quartzoſe part of the matrix remains; when loaded, the globule grows milky. The third is diſſolved with little effervefcence, and the globule is obſcured, is a little blue (from the copper); but by long fuſion the tinge vaniſhes; if continued too long, it is rendered opake.

It is to be obſerved of each of them, that during ſolution flaſhes break forth, ſuch as are deſcribed proceeding from the metallic zinc, but ſmaller and leſs frequent.

Borax, with a ſmall quantity of the firſt, grows yellow, with a larger quantity black,

 and

and that almoſt without any effervefcence. The ſecond is more ſlowly taken up, yielding a yellowiſh green glaſs: by too much an opacity is contracted.

Mineral alkali attacks the firſt with vehement ebullition, producing grains of lead, although no galena appears mixed with it even by a glaſs. The ſecond is alſo taken up with effervefcence, forming an hepatic maſs, which is alſo true of the third; but theſe yield no metal.

§ III. *Analyſis of calcined Zinc.*

We ſhall now examine a variety of lapis calaminaris, which, in the manufactories where braſs is prepared, is called Hungarian lapis calaminaris.

(A) 100 lb. of this ſtone, to which were added 165 of concentrated vitriolic acid, generated ſo great a degree of heat, as to raiſe the thermometer in a few moments from 15° to 65°, and a white ſmoke breaks forth, which yet could not paſs through the tube of an alembic without the aſſiſtance of fire. This ſmoke, collected in diſtilled water, exhibited the ſame phænomena as are mentioned in the following paragraph, and therefore is of a vitriolic nature (§ IV. D).

(B) 100 parts of this mineral, well calcined, loſes ſcarcely any of its weight; ſo that if it contains any aerial acid, the quantity is ſo ſmall as not to be ſenſible on weigh-

ing;

ing; for the ſmall obſervable decrement muſt be aſcribed to the humidity. The ſame is alſo confirmed by ſolution in acids, for no efferveſcence appears in this operation.

(c) A double weight of nitrous acid was poured upon 100 of the ſame ore, which being evaporated to dryneſs, the ſame quantity was twice more added, and in like manner expelled by fire; this was done that the iron being calcined might remain inſoluble: during this operation the vapours were ſomewhat red.

The maſs being again put into nitrous acid, the zinc alone was diſſolved by phlogiſticated alkali, and a white ſediment was precipitated, which, when waſhed and dried, weighed about 359 lb. The inſoluble reſiduum, well elixated and dried, weighed nearly 16 lb.; this, with three times its weight of concentrated vitriolic acid, was evaporated to dryneſs in a ſand bath; a ſolution was then extracted with diſtilled water, which yielded, by means of phlogiſticated alkali, about 12 lb. of Pruſſian blue: the liquor remaining produced, by ſubſequent cryſtallization, a true alum, but in very ſmall quantity.

Finally, there remained 12 lb. which eluded the force of the acids, and which was of a ſiliceous nature.

(D) All theſe being conſidered, there are found in 100 of this lapis calaminaris, 84 of calcined zinc, 3 of calcined iron, about 1 of pure clay, and 12 of ſiliceous earth.

 (E) This

(E) This analyſis has alſo been conveniently performed in another way: firſt, by abſtracting vitriolic acid, then elixating with water, finally precipitating by cauſtic volatile alkali, and diſſolving. The reſiduum, which reſiſts the vitriolic acid, is ſiliceous earth; that which refuſes the volatile alkali contains a calx of iron with pure clay, which, when diſſolved in vitriolic acid, may be ſeparated by phlogiſticated alkali.

(F) We ſhall finiſh by adding ſomewhat here concerning the calx of zinc, artificially prepared, which commonly goes by the name of flowers of zinc. Theſe are eaſily and totally diſſolved by acids, generally without any motion, but ſometimes with a vehement effervefcence. Some flowers, which had been made by Von Swab in the year 1742, were quietly diſſolved after the ſpace of thirty-ſeven years; whereas others, made in 1758, excited a violent effervefcence like chalk, inſomuch that one would be induced to ſuppoſe at firſt that chalk was mixed with them; but upon examination nothing heterogeneous was found. The elaſtic fluid which was extricated ſhewed, upon examination, all the properties of aerial acid. This difference is undoubtedly occaſioned by the quantity of the aerial acid ſurrounding the maſs during calcination, and ſhews that the dephlogiſtication may be effected without the reception of that acid.

The

The flowers, which are extremely white, expoſed to the action of dephlogiſticated marine acid for ſome days in a cloſe veſſel, grow almoſt black, but are not (like white arſenic) reſolved into an acid liquor.

§ IV. *Analyſis of aerated Zinc.*

The ſpecimen of aerated zinc firſt examined, was that brought from Holy-Well in England, the ſame which had been examined before by the blow-pipe (§ II.)—Of this

(A) 100 lb. reduced into a ſubtile powder, loſt by calcination 34 lb. but did not betray the ſlighteſt traces of a ſulphureous odour.

(B) As it diſſolves in marine acid with effervefcence, and without any hepatic odour, the operation was performed in a chemico-pneumatic apparatus, in order to examine the nature of this volatile vapour. 100 lb. in this way yielded only ten cubic inches of elaſtic fluid; but the water through which it paſſed, amounting to 30 inches, was found almoſt ſaturated. In order therefore to determine it more accurately, it was collected in mercury, and exhibited about 28 cubic inches, which were all abſorbed by diſtilled water, and imparted to it all the properties communicated by aerial acid. Now 28 cubic inches of that acid, in a moderate temperature, weigh about ſo many aſſay pounds, but in calcination 34 are loſt;

ſix therefore remain, which doubtleſs are owing to water, for it appears from (D) that no aerial acid is preſent.

(C) The experiment was repeated in the ſame way, but the vitriolic acid employed inſtead of the marine; an equal bulk of aerial acid was produced.

(D) In order to diſcover whether any veſtiges of marine acid remain hid in this ore, to 100 parts, reduced into a very ſubtile powder, were added 165 of concentrated vitriolic acid, in a ſmall cucurbit fitted with an head, the orifice of whoſe tube was plunged under diſtilled water. No ſmoke or ſmell was perceived. The cucurbit was therefore placed in a ſand bath, and fire being applied, the mixture at length ſent forth a white ſmoke, which, paſſing through the water, there depoſited whatever acid it contained, and the water loaded with this fume reddened paper tinged with turnſole. Some drops of a ſolution of nitrated ſilver were dropped into a ſmall portion of this, upon which clouds aroſe, but theſe quickly vaniſhed upon the addition of a quantity of diſtilled water. But as vitriolated ſilver is much more ſoluble than ſalited ſilver, a ſuſpicion aroſe of the preſence of vitriolic acid, which was further confirmed by the dropping in of nitrated mercury prepared without heat; for the white ſtriæ which appeared upon this inſtillation, upon the further addition of a large quantity of water fell to the

bottom

bottom in the form of a yellowiſh powder: beſides, the addition of ſalited terra ponderoſa to another portion, immediately generated a ſpathum ponderoſum, the moſt certain ſign of vitriolic acid. If therefore marine acid be preſent in ſome vitriform ores of zinc, this muſt be conſidered at leaſt as accidental, and by no means neceſſary to their compoſition.

(E) Vitriolic acid takes it up almoſt entirely, leaving ſcarcely 00,1 remaining undiſſolved; and evaporation being continued to dryneſs, ſo as to expel the ſuperfluous acid, the ſolution, on the addition of water, yields by cryſtallization 326 lb. of white vitriol.

(F) Phlogiſticated alkali, added to a ſolution of this vitriol, throws down a mixed maſs, white and ſpongy, yet containing a few particles of Pruſſian blue; which ſhews that a ſmall quantity of iron is preſent. It is worthy of obſervation, that the blue atoms gradually become of a browniſh red; whether they be ſuffered to remain in the liquor for ſome days, or whether they be ſeparated by filtration, waſhed, and dried.

(G) 100 parts of vitriform zinc, with powdered charcoal, and 150 of copper, treated in the uſual way, communicated to the copper an increment only of 15 lb. though in this operation a great part of the zinc always is deſtroyed by deflagration.

(H) Upon

(H) Upon comparing all the experiments, it plainly appears, that in 100 of this English mineral there are 28 of aerial acid (B, C), 6 of water (B), and of calcined zinc (with a very ſmall portion of ochre ſcarce exceeding 1) about 65 (E, F).

(I) For the ſake of compariſon it muſt be added, that the artificial glaſs of zinc, ariſing from the diſtillation of this ſemi-metal, diſſolves in acids without any efferveſcence; ſo that it alſo contains more zinc, and the other variety mentioned in § II. (B) is produced.

§ V. *Analyſis of vitriolated Zinc.*

Zinc, in a ſaline ſtate, has hitherto been but rarely found, and always united with vitriolic acid; ſcarcely ever pure, but united with vitriol of iron or of copper, or both together. We ſhall therefore firſt examine it in its pure ſtate, in order to diſcover occaſional differences the better.

(A) Vitriol of zinc yields tranſparent cryſtals, clear as water, and without any colour; they exhibit compleat quadrangular priſms, two of whoſe oppoſite ſides are broader; the terminating pyramid has alſo four ſides: in general, however, in the two oppoſite angles of the priſm, a ſmall defect is obſerved, ſo that the ſection becomes hexagonal. The native vitriol is generally ſtalactitic, ariſing from the ſpontaneous calcination

nation of pseudo galena. The crystals rather calcine than deliquesce.

(B) By gentle calcination 100 loses about 40, which consist of water.

After a white heat of three hours, no more remained than 20 of ashen brown coloured powder; yet that metallic zinc, by calcination, is encreased at least 0,17, plainly appears, for 20 of calx are produced from little more than 17 of the metal: 100 of white vitriol therefore contains 20 of calcined zinc, 40 of vitriolic acid, and 40 of the water necessary to crystallization.

(C) In a moderate temperature 100 of the crystallized vitriol require to dissolve them 228 of distilled water. By a boiling heat much more is taken up.

(D) If to a solution of the 100 just mentioned, be added a phlogisticated alkali, whitish particles are soon separated; which, collected, washed, and dried, after compleat precipitation, yield 83 of a yellowish white powder. Now, 1 part of metallic (that is 1,17 of calcined zinc) yields to phlogisticated alkali nearly 5, therefore 83 indicate $16\frac{3}{5}$ of metallic zinc; which agrees altogether with an experiment already tried in another way (B).

(E) A solution of 100, precipitated by aerated alkali, yields a white powder, in weight 38, which is taken up by acids with an effervescence which continues till the very last particle is dissolved; therefore 20

of

of calcined zinc are able to fix 18 of aerial acid and water together. Hence we derive an illuſtration of what has been already ſaid concerning its effervefcence in acids (§ IV. F.). Zinc, when once calcined without aerial acid, afterwards attracts it ſcarcely at all, or at leaſt very ſlowly.

(F) White vitriol, mixed with green, blue, or both, cannot be ſeparated from them by cryſtallization.

The mixture may in ſome degree be judged of by the colour. The form of the cryſtals is ſpathaceous, even though the inquinament does not exceed $\frac{1}{4}$. The phlogiſticated alkali betrays copper by a browniſh red, and iron by blue particles, the former of which, particularly, diſtinctly appear on the firſt inſtillation, mixed with the white, provided the liquor be not ſhaken. On the addition of zinc, both the copper and iron are precipitated.

§ VI. *Analyſis of the black Pſeudo Galena of Dannemer.*

I have tried by various methods to diſcover the compoſition of the pſeudo galena, but ſhall here only mention thoſe which ſeemed peculiarly adapted to the purpoſe in each particular caſe.

(A) By a white heat of four hours, 25 out of 100 flew off; at the ſame time a ſtrong ſmell of ſulphur was perceived, ſcarcely mixed

mixed with that of arſenic, but no flame, nor were any flowers of zinc diſcernible; the colour of the roaſted powder was like that of bricks.

This operation being finiſhed, the quantity of volatile matter is generally eſtimated from the decrement of weight; but when we are examining ores by this method the quantity is made leſs than it ought, as metals gain weight by calcination. Lead gains about 0,12, copper 0,16, zinc 0,17, and iron 0,36. In the preſent caſe, the quantity of the metals otherwiſe known (if they be ſuppoſed in a perfect ſtate) ſhews that by the dephlogiſtication the weight of the remaining maſs is encreaſed by 12. This correction therefore ſhould not be neglected.

(B) Six hundreds of the pſeudo galena being expoſed to heat in a cloſe apparatus, no elaſtic fluid appeared; a little ſulphur was ſeparated, and nearly 6 lb. of reguline arſenic collected in the upper part, as alſo about 36 of water in a tube fitted for receiving it; viz. to the extremity of the alembic tube, turned upwards, was faſtened a wet bladder well emptied of air by preſſure: during the operation it was a little inflated, but on cooling collapſed again; the water filled the tube; the reguline arſenic covered the upper part of the cucurbit with a black ſcale.

(C) As lead is found in this ore (§ 11.), the 75 parts remaining were boiled in marine acid ſo long as any thing was diſſolved; to the

the ſolution, filtered, and inſpiſſated by evaporation, was added vitriolated volatile alkali, by which a vitriol of lead was partly ſeparated inſtantly, and partly by further evaporation. This vitriol yielded about 6 lb. of lead.

(D) The remaining liquor was evaporated to dryneſs; and, for the purpoſe of calcining the iron, nitrous acid was repeatedly evaporated from it, the laſt time even to ignition. Finally, it was diſſolved in that acid; but there remained 13 of calcined iron, which is equivalent to about 9 of the metal.

(E) A ſolution of zinc, precipitated by phlogiſticated alkali, yielded a whitiſh yellow ſediment, weighing 223 lb. which indicate nearly 45 of metallic zinc (§ V. D).

(F) The marine acid mentioned in (B) was reſiſted by 4 parts, which diſſolved with great difficulty in microcoſmic ſalt, but more eaſily in borax, and in mineral alkali with effervеſcence: theſe properties indicate a ſiliceous nature.

(G) Upon a juſt calculation, therefore, it appears, that the 100 under examination contains 29 of ſulphur, 1 of regulus of arſenic, 6 of water, 6 of lead, 9 of iron, 45 of zinc, and 4 of ſiliceous earth. There is no doubt but that the proportions vary a little in the various ſpecimens: beſides, in order to determine all the quantities with preciſion, it would be neceſſary to know the deficiency of phlogiſton occaſioned in me-

 tals

tals by their union with ſulphur; a circumſtance which however is yet unknown: ſomewhat is certainly loſt, but it ſhould appear the loſs is but ſmall.

§ VII. *Analyſis of the brown Pſeudo Galena of Sahlberg.*

(A) The brown pſeudo galena of Sahlberg, properly roaſted, loſes only 0,13, of which 5 are water. The ſulphureous odour is leſs perceptible in this than in the former analyſis.

(B) Nitrous acid was repeatedly abſtracted from the other 87 parts, even to ignition, and afterwards whatever that menſtruum could take up was diſſolved.

(C) The ſolution, on examination, only yielded zinc, which when precipitated by phlogiſticated alkali yielded 218 lb. of ſediment, and then by volatile alkali 3 parts of clay.

(D) From the remaining 31 parts, which reſiſted the nitrous acid, the vitriolic was abſtracted to dryneſs; upon which it was elixated with diſtilled water, and 24 only remained.

(E) The ſolution of (D), precipitated by phlogiſticated alkali, yielded 29 parts of Pruſſian blue, which nearly correſpond to 45 of iron.

(F) The Pruſſian blue being ſeparated by filtration, the liquor had an aluminous

taſte;

taſte; and this ſalt alſo appears upon cryſtallization, but mixed with vitriolated vegetable alkali.

(G) The 24 parts untouched by the acids, were the reliquiæ of a quartoſe matrix.

(H) Therefore 100 of this ore contains about 17 of ſulphur, 5 of water, 44 of zinc, 5 of iron, 5 of clay, and 24 of quartz.

It is probable that in this inſtance the zinc is more dephlogiſticated than in the others. Hence, from the unknown quantity of the difference, an error ariſes, perhaps of ſome pounds, which as yet cannot be determined.

§ VIII. *Analyſis of the Pſeudo Galena of Boval, which poſſeſſes a metallic Splendor.*

(A) 100 of the pſeudo galena of Boval, loſt by roaſting 17, which by their ſmell ſeemed to be nothing but ſulphur; but diſtillation ſhews that a ſmall quantity of water is alſo mixed with them.

The reſiduum grows black on calcination.

(B) The 83 parts which remained were wetted with three times their quantity of concentrated vitriolic acid, and evaporated to dryneſs; then all the ſaline part was ſeparated from the white maſs, by boiling in diſtilled water, and 6 parts remained which eluded the action of the menſtruum; which were with difficulty taken up by microcoſmic

mic ſalt; more readily by borax, but very eaſily, and with effervefcence, by mineral alkali; at the ſame time the laſt globules were brown: hence it appears that they conſiſt of a ſiliceous and martial matter.

(c) In this inſtance the colour of the ſolution does not betray copper, which yet is ſhewn by the microcoſmic ſalt (§ 11.); but the addition of iron ſoon removes all doubt. In order to determine the quantity of this metal, a poliſhed plate of iron was boiled in the ſolution as long as any of it continued to be taken up. The cupreous ſediment, collected, waſhed and dried, weighed 4 lb. The plate was found to have loſt 6 lb.

(D) In the remaining liquor phlogiſticated alkali precipitates at once a white and a blue ſediment, which indicates the preſence both of zinc and iron. In order to determine the proportions, this liquor, evaporated to dryneſs, was long calcined in the open fire; afterwards nitrous acid was repeatedly abſtracted to dryneſs from the maſs, that the iron, ſpoiled of phlogiſton, might be rendered inſoluble in that acid:—nor was the experiment unſucceſsful, for the zinc alone was taken up, and about 19 lb. of calcined iron remained, which are equivalent to 14 parts of regulus, the weight being increaſed 0,36 by calcination.

(E) The ſolution, containing zinc precipitated by phlogiſticated alkali, yields 259 parts of white ſediment, waſhed and dried.

 (F) 100

(F) 100 of this ore, therefore, contains 52 of zinc, 8 of iron, 4 of copper, 26 of ſulphur, and 4 of water, together with 6 of a ſiliceous and martial matter.

(G) That the metals exiſt either in a ſtate nearly reguline or but little dephlogiſticated, eaſily appears both by the metallic ſplendor, and the violence and redneſs of the vapours with which the nitrous acid attacks them; and, finally, by the union with ſulphur. The ſame is nearly true of the ore of Dannemer, which, although deſtitute of metallic ſplendor, exhibits the ſame phænomena with nitrous acid (§ IX. C); and, beſides, on ſublimation, it exhibits a reguline arſenic (§ VI. B). But the pſeudo galena of Sahlberg ſeems to contain a ſmaller portion of phlogiſton.

(H) It follows, from the analyſis of pſeudo galena, 1. that lime, though it be ſometimes preſent, is not neceſſarily required; for the three varieties I examined did not ſhew the ſlighteſt trace of it, even when the acid of ſugar, its niceſt teſt, was employed: it is certain, if the ſulphur was here united with zinc in the ſtate of an earthy hepar, that a ſmall quantity of lime would not ſuffice, and part at leaſt of the hepar might be elixated by water. 2. That the preſence of cobalt and ſilver is accidental, as alſo of lead and arſenic in the Dannemer pſeudo galena, and of copper in that of Boval. 3. That zinc, iron, and ſulphur, are always preſent;

present; for zinc cannot be united with sulphur, but by means of iron. When these three ingredients are fused together, an artificial pseudo galena is easily made. But it may be gathered from the water, that nature has effected the union in the humid way.

§ IX. *The Phænomena of the hepatic Smell, extricated by Acids from Pseudo Galena.*

When the vitriolic or marine acid is poured on pseudo galena, an hepatic odour is exhaled; but it may be gathered from what goes before, that no alkaline salt nor absorbent earth is present, and therefore no hepar. Hence the cause of this phænomenon may be properly enquired after. —The following experiments will serve to solve the problem.

(A) Six assay 100 of black pseudo galena from Dannemer, well pounded, were put into a glass, and the bulb of the thermometer was set in the midst of it. 300 of concentrated vitriolic acid being poured on, a few bubbles arose, and a distinct hepatic odour was perceived. In four minutes the mercury arose from 16 to 27; but in nine it began to sink. The powder was so much indurated, that it was difficult to separate the thermometer without breaking it.

(B) The experiment was repeated with 200 of smoking marine acid. A strong hepatic odour, and a violent effervescence, were

 observed;

obſerved; but the mercury in the thermometer remained without motion.

(c) 200 of ſmoking nitrous acid, diluted with an equal quantity of water, were poured on the ſame weight of ore, when an intumeſcence was perceived, and red vapours aroſe, without any hepatic ſmell. A heat of 74° took place in four minutes.

The reſiduum, after having been well waſhed with hot water, produced no hepatic ſmell, either with the vitriolic or marine acids.

(D) The hepatic vapour, extricated with the aſſiſtance of heat by vitriolic acid, out of a quintal, and collected in quickſilver, amounted to two cubic inches; but the marine acid produced ſeven from the ſame quantity. The red fumes ariſing when nitrous acid is employed were found on examination to be nothing but what is called nitrous air.

(E) One-half of a quadrant of hepatic air, collected in an inverted phial, and mixed with an equal portion of nitrous air, becomes grumous, and depoſits ſulphur; and the mercury in the thermometer ſuſpended in it roſe to 6°.

(F) Yet all the pſeudo galenæ are not equally affected by acids: if marine acids be poured on the three above examined, that of Dannemer emits an hepatic air, with many bubbles; from that of Boval fewer bubbles riſe; and from that of Sahlberg, ſcarce

ſcarce any. The two firſt yield a very offenſive ſmell, even though kept in corked bottles for a number of years: the laſt has but a faint ſmell, which continues only for a few minutes: the others, boiled with acids, ſcarce extricate any hepatic odour.

(G) $2\frac{1}{2}$ cwt. of yellow lapis calaminaris from Hungary, treated in the ſame way as the pſeudo galena, occaſioned with vitriolic acid a degree of heat $= 65°$, but no hepatic ſmell was perceived.

(H) The ſame ſtone generated heat with nitrous and marine acid, but without any hepatic ſmell.

(I) Flowers of zinc occaſion with acids heat, but no ſmell.

§ X. *Explanation of the hepatic Odour.*

From the phænomena above mentioned the origin of the hepatic odour is eaſily ſeen both analytically and ſynthetically. We ſhall firſt examine it *analytically*.

(A) That ſulphur enters the compoſition cannot be doubted, as it is actually found precipitated (§ IX. E): but we are to enquire the cauſe which in this inſtance dilates the ſulphur which had been ſo ſubtilely diſſolved into an aeriform elaſtic fluid.

(B) That heat exiſts fixed in hepatic air, and is ſet at liberty by the deſtruction of that air, evidently appears from the aſcent of the mercury (§ IX. E.) The opinion that the heat of bodies conſiſts in a certain inteſtine

 motion

motion of their parts, is at preſent held to be totally improbable. Many circumſtances tend to prove, that heat is to be attributed to a matter diſtinct from all others, which when diſengaged occaſions ſenſible heat in proportion to its quantity; but ſo long as it conſtitutes a primary principle of bodies, its power of heating is repreſſed (in the ſame way as the properties of an acid ſaturated with alkaline ſalt) which power, however, it again recovers, when by any means ſet at liberty; hence, in certain ſolutions, heat is generated; namely, when that principle which had been united with one of the ingredients is expelled by a ſtronger attraction: in others cold is produced, occaſioned by the heat entering into the new compound. Since, therefore, on precipitation of ſulphur from hepatic air, heat is generated, we may conclude that the matter of heat had been before fixed. This concluſion will be further confirmed hereafter (E.)

(c) It appears plainly, that the phlogiſton in hepatic air forms the bond of union between the matter of heat and the ſulphur; for that air cannot be decompoſed, except by ſubſtances which are extremely greedy of phlogiſton: concentrated nitrous acid poſſeſſes this power, even in water loaded with hepatic air; nay, nitrous air, although ſo much loaded with phlogiſton that its acid properties are concealed, produces the

7 ſame

ſame effect (§ IX. E.) We ſee therefore, that upon the abſtraction of phlogiſton the whole compoſition is deſtroyed, ſo that it may juſtly be conſidered the bond of union. Sulphur, by means of heat alone, diffuſes no hepatic ſmell.

All this is completely eſtabliſhed by a right conſideration of the principles of the pſeudo galena, and its different habits with reſpect to acids. We now proceed to examine this ſubject *ſynthetically*.

The conſtituent parts of hepatic air being thus diſcovered by analyſis, let us now examine ſynthetically whether theſe are to be found in the pſeudo galena.

(D) Of ſulphur we can have no doubt, as even the quantity of that has been already determined (§ VI.—VIII.)

(E) The preſence of the matter of heat is equally certain, for the pſeudo galena with nitrous acid excites a conſiderable degree of heat (§ IX. C.); and the vitriolic acid generates with it a degree of heat, though leſs. Thus we ſee the matter of heat more or leſs ſet at liberty.

(F) Beſides the phlogiſton of the ſulphur, no ſmall portion of that principle adheres to the metals, as has already been evinced (§ VII. G.)

All the principles therefore before diſcovered by analyſis are preſent (A—C.)

(G) It may now be queſtioned, whether theſe principles are ſo united in the pſeudo

 galena

galena as actually to conftitute hepatic air, which, like the aerial acid in chalk, lies hid; or whether it be on the addition of the proper acid that they firft coalefce and form an elaftic fluid.

(H) In order to determine this queftion, the pfeudo galena was fubjected by itfelf to diftillation; and the vapour extricated was collected in a pneumatic apparatus: but on examination nothing was obtained but a fmall portion of water, and nothing at all aerial: befides, all the different acids would expel the fame quantity, if the hepatic air lay hid, like the fixed air in chalk; but we have feen, that from 1 cwt. none was obtained by nitrous acid, two cubic inches by the vitriolic, and feven by marine acid (§ IX. D); the elaftic fluid therefore does not pre-exift in a perfect ftate.

(I) It is generated therefore during the folution; for the addition of the acid, by loofening the texture of the mafs, fets the heat at liberty, together with the phlogifton of the zinc and iron; for no metal is taken up by acids, until it is dephlogifticated to a certain degree. The firft effect therefore of acids upon metals is to deprive them of that portion of their phlogifton which prevents their folution, and by this privation they become foluble.

Thefe two principles, heat and phlogifton, being fet at liberty, feize the fulphur which they meet with, combine with it, and

and form an elaſtic fluid; but as the nitrous acid attracts and retains phlogiſton with more force than the reſt, with it a great heat is generated, but no hepatic air can be formed, for the principle which ſhould connect the other two is wanting. The vitriolic acid indeed attracts phlogiſton leſs powerfully than the nitrous, but does not yield up all that it ſets at liberty to the generation of hepatic air; and this air is conſequently produced only in ſmall quantity, indeed ſo ſmall that ſome heat remains at liberty: but the marine acid, being naturally loaded with phlogiſton, does not attract any more; therefore the whole of the heat may very eaſily be fixed by the phlogiſton extricated by this acid from the metals; hence, with this acid, there is no heat generated, but a conſiderable quantity of hepatic air. The calcined pſeudo galena retains, indeed, the matter of heat, but loſes the phlogiſton and the ſulphur in the fire; therefore no veſtiges of hepatic air can ariſe here, as with the lapis calaminaris (§ IX. F, G.)

All theſe circumſtances agree ſo perfectly, that no doubt can remain of the truth of the explanation; yet pſeudo galena is not to be conſidered as the only body in nature which can produce an hepatic air and odour on the addition of acids: it is enough to mention galena, which occaſionally exhibits the ſame phænomena; for the marine acid acts moſt efficaciouſly, but the nitrous ſhews not the leaſt

leaſt veſtiges of any thing hepatic; and in this caſe the vitriolic acid has little effect, as it hardly attacks lead, when in a metallic ſtate. It is alſo worthy of obſervation, that native Siberian iron, with marine acid, diffuſed a diſtinctly hepatic ſmell; but the examination of this would require a ſeparate treatiſe.

§ XI. *Phoſphoric Quality of the Pſeudo Galena.*

Some varieties of pſeudo galena upon friction ſhine in the dark; and among thoſe the moſt remarkable is that which is found at Scharfenberg, in Miſnia. This, when rubbed with glaſs, a bone, iron, or any hard ſubſtance, emits a fœtid ſmell; and at the point of contact ſends forth a flame of a gold colour, and this happens in water, nay, even in acids, and it retains this property even after a violent white heat. Some inſiſt that this light is electric; but the electric flaſh is of a very different kind, being entirely extinguiſhed by water, whereas this is made rather more ſplendid. Latent light is not the cauſe, for in ſolution no light is occaſioned.

Suppoſing that light be nothing but the matter of heat, with a determined ſuperabundance of phlogiſton, theſe principles are not deficient in the pſeudo galena; for we we have already ſeen that the matter of heat is really preſent (§ X. B, E), and at the ſame time phlogiſton (§ X. C, F). The firſt, therefore, excited and ſet at liberty by friction, may eaſily ſeize the latter, and produce light.

Many varieties do not ſhine at all, ſome ſcarcely, and a few very remarkably; this is undoubtedly owing either to the proportion of the principles, or their cloſeneſs of connection; which laſt opinion is confirmed by obſerving that thoſe which poſſeſs the phoſphoric quality in the moſt eminent degree reſiſt the three mineral acids, ſo that either no hepatic odour or heat ariſes, or at leaſt much weaker than in the others, which indicates a firmer texture; yet all that reſiſt the acids are not found to be phoſphoric. This difficulty is ſolved by the analyſis of the pſeudo galena of Scharfenberg, the ſcarcity of which has as yet prevented the experiment from being ſufficiently varied. The powder, expoſed alone to fire in a cloſe veſſel, yields a ſiliceous ſublimate, ſimilar to that produced by mineral fluor and vitriolic acid. The fluor acid is therefore preſent, but probably united in ſuch a manner to the metallic baſe, that it cannot, by fire alone, be expelled, and generate with water a ſiliceous earth.

Marine acid by boiling diſſolves it, when well powdered, almoſt entirely, and produces an hepatic ſmell; for, excluſive of the ſulphur,

phur, ſcarce more than 0,01 remains, which, examined by the blow-pipe, appears to be ſiliceous. In 100 the zinc forms nearly 64, iron 5, ſulphur 20, water 6, fluor acid 4, and ſiliceous earth 1;—nothing calcareous is found.

This pſeudo galena is lamellated, yellow, and ſemipellucid; but, ſituated in a certain way with reſpect to the eye, it appears opake, ſomewhat reſembling a metal, like moſt of the others. The various proportions ſeem to indicate, that in this inſtance the metals are not preſent fully calcined. Fuſed with microcoſmic ſalt by the blow-pipe, it throws out a few flaſhes almoſt like that of Sahlberg, which was mentioned among the Swediſh pſeudo galenæ (§ 11.), a phænomenon which can hardly be produced with calcined zinc. With nitrous acid it produces certain vapours. It is indeed true, that it excites a very ſmall detonation; for the firſt parcel thrown into nitre, well fuſed, occaſions nothing but an efferveſcence; and it is not until the fourth or fifth addition that ſparks are produced, and even theſe are few. The Swediſh pſeudo galenæ, firſt examined, detonate on the third or fourth addition: this difficulty of detonation rather points out the cloſeneſs of connection in the inflammable principle, than a deficiency of it; for on the ſame ground we might diſpute the preſence of ſulphur, which yet is moſt certainly preſent.

DISSER-

DISSERTATION XXIII.

OF

METALLIC PRECIPITATES.

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§ 1. *Design of the Work.*

THE man who firſt ſaw a metal corroded by a limpid menſtruum, in ſuch a manner that a body ſo extremely ponderous and ſo opake ſhould gradually and entirely diſappear, and afterwards, upon the addition of a ſuitable precipitant to a liquor which appeared to be ſimple and homogenous, ſaw that metal ſeparate, and again come into view;—the man, I ſay, who firſt ſaw this, muſt have been ſtruck with aſtoniſhment and admiration. Perſons accuſtomed to theſe wonderful phænomena neglect

neglect perhaps too much the accurate investigation of them, though these operations are of the highest importance, and form as it were the whole of the effective part of chemistry. The phænomena of this kind are so various and so intricate, that a single volume would be utterly insufficient for examining them all: we shall here therefore only examine such as relate to the separation of metals from acids, particularly with regard to the weight of the precipitate. Weighing is, no doubt, a mechanical operation, but yet is of singular service not only in investigating the properties of bodies, but in directing those properties to their proper uses. All effects are exactly proportioned to their causes; therefore, unless their mutual relations be examined by accurate trials, theory (of consequence the whole of natural philosophy) must be lame and imperfect.

That we may the better understand the nature of precipitations, we shall briefly examine the phænomena of metallic solutions in general.

§ II. *Examination of Metallic Solutions.*

A small piece of a metal being put into an acid, is taken up slowly or quickly, with violence, or gently, according to the various nature of the metal and the menstruum.

(A) As

(A) As to menſtrua, when unaſſiſted by heat, the nitrous acid is found the moſt powerful, ſo much ſo as ſometimes to exceed the bounds required; and the metal diſſolved is again ſeparated, unleſs the violence of this acid be properly tempered: yet ſometimes the nitrous acid alone has no effect, as is the caſe with gold and platina; but when the nitrous is united with the marine acid, the ſolution is readily effected.

The vitriolic acid, though very highly concentrated, yet acts more weakly. It does not attack mercury or ſilver, unleſs when boiling; and gold and platina elude its force, even though boiled to dryneſs.

Marine acid acts ſtill more weakly, unleſs it be dephlogiſticated (*a*); in which ſtate it diſſolves all metals compleatly.

The other acids, as the fluor acid, the acids of arſenic and borax, and all thoſe obtained from the organized kingdom, are in general inferior in ſolvent virtue to the preceding.

(B) With reſpect to the metals, ſome are very eaſily diſſolved, others not without great difficulty, and that in the ſame menſtruum. Zinc and iron are readily diſſolved in every acid; ſilver eludes the marine, and gold even the nitrous acid. Yet theſe metals, which in their natural ſtate obſtinately

(*a*) Nov. Act. Upſal, vol. ii.

reſiſt

resist solution, may be made soluble by depriving them of a proper proportion of their inflammable principle. I expressly mention a proper proportion, for experience shews, that iron, and particularly tin, are made refractory by too much dephlogistication; but nothing more plainly shews the limits of this process than manganese, which when calcined to blackness cannot be dissolved without the addition of some inflammable matter, but when reduced to whiteness dissolves in all acids (*b*).

(c) If we consider the manner of the solution with accuracy, we shall find that the diminution of complete metals, even to the last visible particle, is accompanied by an effervescence; that is, innumerable air-bubbles continually rise from the surface of the metals, and float to the surface of the surrounding liquor. These are the more frequent, in proportion to the quickness of the solution, and are very few, and scarcely visible, when it proceeds very slowly.

The elastic fluid, which is thus extricated from metals by nitrous acid, if collected by a proper apparatus, and examined, is found to be nothing more than what is commonly called nitrous air; but when the menstruum is concentrated it absorbs a considerable quantity of this air. By means

(*b*) See the Treatise on the white Ores of Iron.

of vitriolic acid inflammable air is obtained from zinc and iron, as alſo by means of marine acid; but from the other metals diſſolved in vitriolic acid, we obtain another ſpecies of air, called *vitriolic acid air*; and by the marine acid, another ſimilar to the former, called *muriatic air*, but both more or leſs mixed with inflammable air.

(D) Frequently, during the ſolution of a metal, heat is generated in the liquor, the intenſity of which follows the compound ratio of the bulk of the maſs, and the quickneſs of ſolution; therefore, when the maſs is very ſmall, and the ſolution proceeds very ſlowly, the temperature ſcarcely ſuffers any alteration.

(E) The calxes of metals, during ſolution, either give out no air at all, or elſe the aerial acid; unleſs when, after being evaporated to dryneſs, they are urged by a violent heat almoſt to ignition; for in this ſtate, by means of vitriolic or nitrous acid, they give out a portion of pure air, which cannot be got by means of marine acid: according to circumſtances, a vitriolic or nitrous air is alſo ſometimes produced, and even that ſpecies which is commonly called phlogiſticated air.

(F) Various metals, when diſſolved, impart certain determined colours to their menſtrua; ſuch are gold, platina, copper, iron, tin, nickel, and cobalt; the reſt, if properly depurated, yield no tinge. A ſolution

lution of ſilver, at firſt, is ſometimes of a blue or green colour, although there be no copper preſent. The vitriolic acid grows blue with copper; the nitrous may be made either blue or green at pleaſure; the marine varies according to the quantity of water with which it is diluted; mangane ſe, when too much dephlogiſticated, renders both the vitriolic and marine acids purple.

§ III. *Explanation of the above-mentioned Phænomena.*

At preſent no one can reaſonably doubt that ſolution is the effect of attraction; we may therefore lay that down as a fundamental propoſition, and proceed to illuſtrate (in the beſt way we are able) the more remarkable circumſtances of the operation, conſidering it not in a general view, but merely as it regards metals.

Upon attentive conſideration it readily appears, that "*no metal can be taken up by an* "*acid, and at the ſame time preſerve the whole* "*quantity of phlogiſton which was neceſſary* "*to it in its metallic ſtate.*" A certain proportion therefore of the principle of inflammability may be conſidered as an obſtacle, which muſt be removed before ſolution can take place. Let us ſee now how this doctrine will apply to the more remarkable phænomena ſeparately conſidered.

(A) Of

(A) Of all the acids the nitrous attracts phlogiston the most powerfully, and separates even from the vitriolic acid. If this be doubted, let sulphur be slowly boiled in concentrated nitrous acid, at length all its phlogiston will be found separated, and the vitriolic acid will remain deprived of its principle of inflammability. The extraordinary solvent power of this acid, therefore, is conformable to the peculiarity of its nature in this respect; for this menstruum adapts metals for solution with the greatest ease, most commonly without any assistance from external heat, which in some instances would be hurtful, by separating too much of the phlogiston. This last case is sufficiently illustrated by iron, tin, and antimony, all which may be so far deprived of phlogiston as to be very difficultly soluble in acids; it is therefore not unfrequently necessary to temper the activity of this menstruum by water.

The vitriolic acid does not act upon silver or mercury, unless when boiling; for by means of the heat the watery part of the acid is diminished, its power is thereby increased, and the connection of the inflammable principle with the metallic earth is diminished.

Marine acid, which contains phlogiston as one of its proximate principles, must necessarily have but little or no effect on those metals which retain their principle of in-

 flammability

flammability very obſtinately; but when boiling, its watery part is diminiſhed, and it aſſumes the form of an aerial elaſtic fluid, in which ſtate it powerfully attracts a larger proportion of phlogiſton than before; but when dephlogiſticated, it attracts phlogiſton with prodigious avidity, readily attacking all metals, and rendering them ſoluble by the abſtraction of their phlogiſton, which it unites to itſelf, and reſumes the ordinary form of marine acid. This acid, when dephlogiſticated in aqua regis by means of the nitrous acid, diſſolves gold and platina.

Upon this principle we can eaſily account for the inferiority of power in the other acids.

(B) As to the metals, they retain their phlogiſton with very unequal degrees of force: a few of them, which are called the perfect metals, effectually reſiſt calcination in the via ſicca. In this operation, on the one hand, the fire, which wonderfully encreaſes the volatility of bodies, ſtrenuouſly endeavours to expel the phlogiſton, which certainly is the lighteſt of all material ſubſtances; on the other, the portion of pure air which occurs in the ſurrounding atmoſphere attracts the phlogiſton ſtrongly: experience however ſhews, that theſe two forces united cannot decompoſe gold, platina, or ſilver, to any conſiderable degree; all the other metals yield to theſe forces when united, but not ſingly. Iron and zinc retain their inflammable principle

ciple ſo ſlightly, that any acid immediately acts upon them; but if, by dry calcination, metals be properly prepared, the menſtrua will immediately take them up; nor is there need of any further privation, which, on the contrary, would be injurious, and precipitate what was before diſſolved. For example, let us recollect the effect of the nitrous acid: this, added to ſolution of tin or antimony in marine acid, by its extraordinary violence carries off ſo much phlogiſton that the calxes, being too much deprived of that principle, are precipitated.

(c) We are now come to the moſt difficult point of all, I mean the production of the various elaſtic fluids which reſemble air. The complete diſcuſſion of this ſubject does not properly belong to this place; but, as ſome circumſtances, hereafter to be mentioned, cannot properly be underſtood without a knowledge of the fundamental principles of this phænomenon, I think it neceſſary to give a brief relation of what I have been able to learn on this head, from my own experiments and thoſe of others; ſome of which I apprehend to be certain, and paſt controverſy; others (as yet only plauſible) to be confirmed, corrected, or rejected by new experiments.

A great variety of different aeriform fluids have been obſerved; of theſe eight only are certainly known with reſpect to their compoſition; theſe are the fluids extricated by the vitriolic, nitrous, and marine acids, fluor acid, vinegar, alkaline ſalts, and hepar ſulphuris.

Pure vitriolic acid, expoſed to a violent heat, is indeed reſolved into vapours, but vapours of ſuch a nature, that when the heat is gone they condenſe again into an acid liquor of the ſame nature as before; but if any ſubſtance be added which is loaded with phlogiſton in a ſeparable ſtate, by means of fire an elaſtic vapour is produced, which is not condenſable by the moſt extreme cold, provided it does not come in contact with water. This is the *vitriolic acid air*, which may be totally abſorbed by water; in which caſe the bond of union between it and the phlogiſton is ſo weakened that this laſt gradually flies off, and at length common vitriolic acid is regenerated. We ſee, therefore, that this acid, by means of a ſufficient quantity of phlogiſton, may be expanded into an elaſtic fluid.

The nitrous acid undergoes a ſimilar and more perfect change in a manner ſtill more obvious:—let a ſmall piece of ſilver (for example) be put into nitrous acid, and inſtantly innumerable bubbles ariſe, and float to the ſurface; theſe collected produce the *nitrous air*. The bubbles upon the ſurface of the metal, where the acid particles are ſufficiently loaded with phlogiſton, aſſume an elaſtic and highly dilated form; ſo that

that they rise by their specific levity, and chace one another from the several points of the metal. The nitrous acid saturates itself with phlogiston more greedily than the vitriolic; and therefore the elastic fluid does not unite with water, and retains scarcely any vestige of an acid nature. Synthetical observations agree perfectly with analysis; for upon the access of pure air, which possesses a still greater attraction for phlogiston, the acid yielding it up immediately reassumes its original form and properties; but the nitrous air differs somewhat from the vitriolic also in this respect, that the phlogiston is not only absorbed so far as to obliterate the acid nature, but even beyond that point. This I am convinced of by many experiments, one of which will be sufficient, namely, the decomposition (*c*) of hepatic air by means of nitrous air.

The marine acid exhibits different phænomena: this acid contains phlogiston, and by its means can be resolved into an elastic fluid called *muriatic air*, which is permanent so long as it is kept from the contact of water; but, like the vitriolic, upon the access of water it reassumes the form of marine acid. As this acid naturally contains phlogiston, there is no necessity for an addition: in the mean time this, in the same manner as nitrous air, when in its ex-

(*c*) See Treatise on the Ores of Zinc, § IX. E.

panded ſtate, attracts a ſtill larger proportion of phlogiſton, and that with wonderful avidity.

When the natural quantity of phlogiſton is diminiſhed the marine acid yields another elaſtic fluid of a reddiſh brown colour, poſſeſſing the peculiar odour of warm aqua regia. This does not unite with water, or but in an exceeding ſmall quantity; and, upon the addition of a due quantity of phlogiſton, may be again reduced to marine acid. The experiments made on the black calx of manganeſe and on white arſenic (*d*), which I have often repeated and carefully weighed, I conſider as indubitable evidences of this connection. Whether the marine acid can by any other than theſe two methods be dephlogiſticated, I am as yet ignorant.

The fluor acid abounds with phlogiſton, and therefore may, without any adventitious matter, be reduced to an elaſtic fluid. This air is eaſily diſtinguiſhed from all others, as when hot it corrodes glaſs.

Vinegar alſo naturally contains phlogiſton; and for that reaſon, when well dephlegmated, can produce an elaſtic vapour, which is called *acetous air*.

All theſe elaſtic fluids ſeem to be nothing more than the acids themſelves, expanded by phlogiſton. Perhaps the matter of heat alſo enters into their compoſition.

(*d*) Nov. Act. Upſal, vol. ii.

This

This is alſo the caſe with cauſtic volatile alkali, which yields the *alkaline air*.

Finally, among thoſe elaſtic fluids, the compoſition of which we are acquainted with, we may place the *hepatic air*, in which we have demonſtrated ſulphur (*e*) united with the matter of heat, by the intervention of phlogiſton.

The origin of the other elaſtic fluids is as yet ſo involved in darkneſs, that we can ſcarcely eſtabliſh any thing certain with regard to them: theſe are of four kinds; and, in conformity with the received opinion concerning their properties, are called *fixed air*, *phlogiſticated air*, *dephlogiſticated air*, and *inflammable air*.

Of the firſt I think it is evidently demonſtrated to be of a peculiar nature, and always acid. Dr. Prieſtley conſiders it only as a modification of nitrous acid; nay, he urges that the vitriolic and nitrous acids are no more than varieties of the ſame ſubſtance. This point I will not abſolutely deny; but the foundation on which theſe aſſertions reſt ſeems to me to be very inſufficient. Thus, in the preparation of ether by vitriolic or nitrous acid, he obtained a conſiderable quantity of fixed air, which he affirms to have been generated during the operation; but we muſt obſerve, that a large proportion of ſpirit of wine enters into this

(*e*) Treatiſe on the Ores of Zinc, § IX. X.

preparation. Now we find that fixed air abounds almoſt every where throughout all organized bodies; why then ſhould ſpirit of wine, which owes its origin to vegetables, be ſuppoſed entirely void of it? As this is very volatile, it is only in a cloſe veſſel that it remains entire, and eludes the force of fire; but when hot, it gives off the fixed air: beſides, by the addition of the ſtronger acid, its texture is broken, and the ſubtile acid, which before was latent, now breaks forth. Add to this, that, whether vitriolic, nitrous, or marine acid, or even vinegar, be uſed in the preparation of ether, aerial acid is produced: either then the aerial acid is common to all the acids (which is by no means confirmed) or it is derived from the decompoſition of the ſpirit of wine; otherwiſe I acknowledge, that the conjecture of fixed air originating from nitrous acid, does not appear improbable; of which we ſhall ſay more hereafter.

That ſpecies of air, which is indiſpenſably neceſſary for the ſupport of flame, and for animal reſpiration, is generally called *dephlogiſticated*. This air, united with a certain quantity of phlogiſton, conſtitutes the matter of heat, as Mr. Scheele has demonſtrated by a long train of experiments, the chief of which I have repeated with the ſame ſucceſs. Setting this down as a principle, let us ſee what alterations ſuch air is liable to. The pureſt air of this kind which can

can be got, cannot be rendered unfit for the ſupport of inflammation or reſpiration, either by flame, by nitrous air, by electrical ſparks, or any other of thoſe operations by which we certainly know phlogiſton to be ſet at liberty; yet it contracts in dimenſion, and is at length entirely conſumed, and that in ſuch a manner that, united with the phlogiſton, it forms the matter of heat, and, being utterly incoercible, pervades all manner of veſſels. A very elegant appearance may be produced by this air; for if a piece of wood, or a candle newly extinguiſhed, be put into a bottle containing it, provided the ſmalleſt particle remains ignited, a flame is inſtantly kindled with a bright coruſcation, and as it were exploſion: this flame is diffuſe and decrepitates, and the eye can ſcarcely bear its ſplendor. When this experiment is performed in an inverted veſſel, the orifice of which is kept beneath mercury, it is evidently ſeen that almoſt the whole of the air diſappears; the remainder amounts to $\frac{1}{8}$, $\frac{1}{10}$, nay ſometimes ſcarcely forms 0,01 of the original bulk; and this reſiduum conſiſts partly of aerial acid, and partly of air unfit for ſuſtaining flame, or being ſubſervient to reſpiration, which had been originally mixed with the pure air.

The ſame thing takes place on the admixture of dephlogiſticated and nitrous air; ſometimes

ſometimes ſcarcely any remains, ſometimes $\frac{1}{10}$ of the bulk, but in general much more. The variations in the quantity of the reſiduum are ſufficient to ſhew the different degrees of dephlogiſtication, or (which is the ſame) the different degrees of purity of the air. This purity may be accounted for in three different ways: for either all its particles may be of the ſame nature with the whole; or a certain number of exceeding pure particles may be mixed with a determined quantity of ſuch as are very impure; or, finally, the different particles, being each endowed with their own peculiar degree of goodneſs, compoſe a maſs of an intermediate nature. Each of theſe caſes may occaſionally take place; but in my apprehenſion the laſt ſeems to be more conformable to the uſual order of nature. With reſpect to the explanation of the phænomena, they all apply equally; but as the ſecond appears to be the moſt ſimple, I chuſe that. Let us now ſuppoſe the perfect nitrous air (which, upon the loſs of phlogiſton, is all reſolved into nitrous acid) mixed to the point of ſaturation with dephlogiſticated air, then all the elaſtic fluid, which had been confined by the glaſs, diſappears, by generating heat and penetrating the veſſel. This takes place if the dephlogiſticated air be perfectly pure; if not, the reſiduum will determine the degree of its impurity. Upon

 this

this principle the beſt common aerial air is ſaid to contain of dephlogiſticated air $\frac{3}{4}$, and the worſt $\frac{1}{4}$.

It is probable that good may be converted into noxious air; this muſt be owing either to the abſtraction of ſomething from the maſs, or the addition of ſome heterogeneous matter to it. The ableſt philoſophers have, by unanimous conſent, determined the latter to be the caſe, and conſider phlogiſton as the cauſe of this corruption.—However, let us for a minute wave theſe opinions, how reſpectable ſoever, and candidly enquire into the truth of the fact, at the ſame time begging pardon for the boldneſs of our attempt.

Let us examine thoſe proceſſes by which phlogiſtication is performed: let us ſuppoſe a lighted candle ſet cautiouſly in air of abſolute goodneſs; we ſhall ſee an exceeding vivid flame, and the candle will be conſumed with extraordinary ſwiftneſs, until a ſmall portion of air remains, which exhibits the properties of aerial acid, proceeding doubtleſs from the tallow, into the compoſition of which that acid enters in great quantity. The phlogiſton, being ſet at liberty by the combuſtion, is ſeized by the pure air, is converted into heat, and penetrates the veſſels; and hence the diminution of bulk which is obſerved. If at firſt there had been more or leſs of air unfit for ſuſtaining flame, that air will be in the end left

left behind entirely unchanged, together with the aerial acid; but in this caſe the diminution of bulk will be leſs.

We have already explained the mode of operation of the nitrous air.

Let a mixture of tin, lead, and biſmuth, which melts by the heat of boiling water, be fuſed in a cloſe glaſs veſſel, the air which is included will be diminiſhed in proportion to its goodneſs; and if this be abſolutely pure, a proportional quantity of the metal will be entirely calcined, and the whole of the elaſtic fluid will diſappear.

Electrical ſparks are ſmall flames, which indicate the extrication of phlogiſton, and at the ſame time generate heat.

All theſe phænomena concur in ſhewing that pure air acquires, by phlogiſtication, ſo great a degree of ſubtlety, that it cannot be confined in glaſs veſſels, nor be any longer inſpired; but no noxious air is produced. Now, if a ſimilar phlogiſtication took place on reſpiration, a ſimilar diminution of bulk would alſo be obſerved, which is contrary to experiments the moſt accurate. Mice, when included in air confined by mercury, and ſuffered to die there, do not occaſion, in general, a diminution of air equal to $\frac{1}{150}$, a loſs which is doubtleſs owing to the ſmall portion of air expelled by the heat of the animal at its firſt introduction. A very different operation ſeems therefore to be performed in the proceſs of reſpiration, from that

that which is carried on during deflagration; perhaps the air rather conveys phlogiſton to the lungs than takes it away. From whence does a pine, growing in the dryeſt ſand, receive its oily matter, is it not from the air? Such animals as by manducation mix a large quantity of air with their food, are obſerved to grow fat in an extraordinary degree. But we ſhall wave thoſe arguments drawn from analogy, and proceed to ſuch as are more direct:—the air in which flame is extinguiſhed, can be breathed almoſt as long as aerial air; neverthelefs, during deflagration, phlogiſton is copiouſly evolved, and by it the pure air is fitted for eſcaping through the veſſels, but is not vitiated, which it always is by reſpiration. Freſh blood, when agitated in pure air, does not diminiſh its bulk, but renders it unfit for ſupporting flame. But if the diſcharge of phlogiſton from the lungs was ſo indiſpenſably neceſſary as the moderns aſſert, undoubtedly inflammable air would be the moſt noxious of all; neverthelefs, the celebrated Mr. Scheele had courage to make the experiment, and to inſpire air, extricated from iron by vitriolic acid, no leſs than 30 ſucceſſive times. After this, its bulk was found the ſame as before; and its inflammability not only deſtroyed, but its nature ſo changed that it extinguiſhed flame. I have myſelf repeated this remarkable experiment

periment with the ſame ſucceſs, except that I was not able to inſpire above 20 times.

Hence it appears at leaſt, that phlogiſton may be abſorbed by the lungs, without any conſiderable danger. I acknowledge, that ſmall animals, when incloſed in this kind of air, ſoon periſh; but this does not, in my judgment, at all tend to ſhew, that the inflammable principle, in more ſimple combinations, cannot be innocent, or even ſalutary and neceſſary, to the animal œconomy. When we conſider the prodigious quantity of this ſubtile principle, which is found in all organized bodies, the powerful effects which the proportion of its quantity produces in the formation of different ſubſtances, we ſhall ſoon ſee the neceſſity of continually repairing the loſs of phlogiſton which the blood ſuffers during circulation from the ſeveral ſecretions. Let the ſagacious obſervers of nature examine carefully this problem; let them deviſe and execute ſuitable experiments, and I truſt that this material point will ſoon be determined. In the mean time, ſince all organized bodies are incapable of flouriſhing, or even of exiſting, without good air, we muſt take leave to call this air *good*, or rather *pure*, until its dephlogiſticated ſtate is evinced by uncontrovertible arguments; and to call that air *vitiated* which is uſually called *phlogiſticated*, as it labours perhaps rather under

under a deficiency than a ſuperabundance of phlogiſton.

I ſhall here briefly explain a theory of aeriform ſubſtances, ſome circumſtances of which I hinted in an oration before the Royal Academy of Sciences, in 1777. Some of theſe circumſtances have ſince appeared to me eſtabliſhed beyond doubt, and others of them only probable, but yet to be ſuch as agreed well together, and are at leaſt worthy of a more accurate examination. Whether the conſequence of this examination be to eſtabliſh or to overthrow them, natural philoſophy will be enriched, and I will not ſpare them myſelf, if by new experiments I ſhall diſcover them to be falſe. In the mean time I hope that a curſory account of them will give occaſion to deciſive experiments.

The celebrated Dr. Prieſtley has ſhewn, by a multitude of experiments, that dephlogiſticated air may be extricated from almoſt all bodies, by means of nitrous acid. He has alſo ſhewn, that this air is found occaſionally more or leſs mixed, ſometimes with aerial acid, ſometimes with nitrous air, ſometimes with that elaſtic fluid which is called phlogiſticated air, ſometimes with all of them together, yet ſo diſpoſed that they generally exhibit themſelves in various order; ſo that from the ſame mixture, expoſed to fire in different veſſels, ſometimes one of theſe fluids will appear firſt, ſometimes intermediate,

termediate, and ſometimes laſt. He has ſhewn that nitrous acid is very greedy of phlogiſton; and that it is wonderfully diverſified by the variety of quantity and connection of this principle. I ſuppoſe it is well known that a large proportion of phlogiſton in a body renders it in general immiſcible with water, &c.

May not therefore the nitrous acid, by a certain quantity of phlogiſton, be converted into aerial acid—the phlogiſton imparting to it elaſticity and levity, weakening its acidity, increaſing its attraction for abſorbent earths, and changing its former properties, or creating new?

May not its acidity be ſo far repreſſed by a ſtill greater quantity of phlogiſton, that it will elude our examination, refuſe to unite with water, be neither eaſily deprived of its phlogiſton, nor any further loaded with it; being unfit for reſpiration by its obſtinate retention of phlogiſton, and for the ſuſtaining of flame by its being no longer able to take up more—thus generating that ſpecies of air which is called phlogiſticated?

May it not, by an abundant quantity of phlogiſton, be perfectly mitigated, and ſo become uſeful both to flame and reſpiration? Thence on the one hand, by any further increaſe of the inflammable principle, it becomes ſo ſubtilized as to generate heat, and thus ſuſtains fire and flame, in which ſtate it pervades all veſſels; and on the other hand, by any

any further diminution of that principle, or (if we may uſe the expreſſion) a determinate calcination, returning occaſionally to the ſtate of phlogiſticated air or aerial aid. Animals provided with lungs are leſs able to dephlogiſticate this air than thoſe which breathe through ſpiracula, or than vegetables; the former converting it into phlogiſticated air, the latter (*f*) into aerial acid. The experiments which have hitherto been inſtituted in another way ſhew a very different effect of vegetation upon air; but if I am not miſtaken the cauſe of the difference depends upon the diverſity of circumſtances. We know that vegetables languiſh, grow tranſparent, and loſe their colour in the dark; but when thus vitiated are ſpeedily reſtored by the rays of the ſun. Light conſiſts of the matter of heat, with an exceſs of phlogiſton; this exceſs is firſt abſorbed, and afterwards by degrees, though with more difficulty, the phlogiſton itſelf, which conſtitutes the matter of heat, is ſeparated; for no vegetation can proceed without heat: and by this proceſs the other principle, the pure air, is ſet at liberty. Therefore, according to the inequality in the degrees of heat, according to the different poſition of the vegetables with reſpect to light, according to their different power in

(*f*) Mr. Scheele found that good air was gradually converted into aerial acid by inſects or vegetables included in it.

decompoſing light and heat, diſſimilar effects muſt neceſſarily take place.—Even water itſelf, which appears ſo ſimple and homogeneous a ſubſtance, frequently contains inviſible organized bodies, which, when operated upon by the ſun's light, by their vegetation produce the ſame decompoſition, and generate pure air.

If the varieties of noxious air can be rendered wholeſome by agitation in water (which I confeſs I have not yet examined with due accuracy) according to our hypotheſis all the varieties, except inflammable air, ſhould be loaded with phlogiſton during the operation. It is known that water always contains a portion of pure air (*g*); and daily experience ſhews, that air diſperſed through water may, by continued agitation, be again collected, eſpecially with the help of a little heat. Do not the emendations of air depend upon this? Water deprived by boiling of its air, ſpontaneouſly recovers it when expoſed to the open air: but water is not fluid without the aſſiſtance of heat, and to that end it requires a degree equal to 72° (*h*). I can ſcarcely believe that the matter of heat undergoes any decompoſition during the agitation; but if that ſhould ſo happen, an air being preſent which wants phlogiſton, a double ſource of pure air will occur; the one by its ſuperabundant phlo-

(*g*) Vol. i. p. 111. (*h*) Vol. i. p. 286.

giſton

giſton correcting the noxious air, the other, by the extrication of phlogiſton, ſetting free the pure air which had before entered into the compoſition of the matter of heat.

But it is not yet ſufficiently clear what rank in this order is to be aſſigned to the *nitrous* air: it abounds with a larger quantity of phlogiſton perhaps than the aerial acid, but more weakly united, on account of the moiſture which the celebrated Fontana has ſhewn to enter its compoſition. Here too we are at a loſs for the reaſon why pure air, already loaded with phlogiſton, is yet able to deſpoil the nitrous acid of that principle.

Inflammable air is undoubtedly charged with abundance of the principle of inflammability; but in other reſpects its compoſition is very obſcure. On the one hand it cannot exiſt in a perfect ſtate in bodies before its ſeparation, as, if that was the caſe, it could be extricated even by nitrous acid; nor on the other, does it ſeem to require the admixture of any particular acid; for it is extricated from iron equally by the vitriolic and the marine, and even by any acid, except that of arſenic, and, what is moſt of all to the purpoſe, without the aſſiſtance of any acid menſtruum whatever, but merely by a proper degree of heat. It is reduced by reſpiration to a vitiated air. If therefore the above theory be agreeable to truth, the principle of it ought to be found in the nitrous

 acid;

acid; but as pure air, on the accefs of a greater quantity of phlogifton, conftitutes the matter of heat; and that which is called inflammable air feems to exceed the pure in quantity of phlogifton, yet does not thereby acquire fubtlety enough to penetrate glafs; there exifts perhaps in this cafe fome peculiar connection: for we cannot eafily conceive that the bare increafe of phlogifton can render the texture of its parts too grofs to pafs the pores of the glafs: we muft however confefs that fulphur, which is perhaps more loaded with phlogifton, is much denfer than vitriolic acid. Yet, although inflammable air diffolves fomewhat of the metal, carries it up, and after depofits it in water, we cannot properly conclude that the metal is neceffary to its compofition: in like manner other heterogeneous matters may be mixed by folution with the other aeriform fluids, and afterwards removed without injuring the properties of the fluids.

Nature proceeds by infenfible gradations; but it is not in our power to follow her clofely, being only capable of diftinguifhing the more remarkable fteps. There is no doubt but other elaftic fluids form intermedia between thofe that we are acquainted with; of this we are the more confident, as we know for certain that pure air, nitrous air, and inflammable air, are not always procured of the fame degree of virtue and efficacy.

If.

If this theory, gathered from ſuch phænomena as are at preſent known, be true, it will not be difficult to underſtand the generation of nitre upon the ſurface of the earth; the inimical nature of aerial acid, with regard to reſpiration, above all other noxious fluids, a property by which it is capable, when taken into the lungs, of deſtroying as it were the original ſtamina of the animal machine; and many other circumſtances hitherto involved in impenetrable darkneſs.

(D) As to the heat generated during the ſolution of metals, it is owing to the matter of heat which had been fixed in the metals, and is now ſet at liberty by the acid menſtrua. All metals are eliquated by fire, ſo that we cannot determine whether this depends upon the fire uſed in fuſion, or whether it belongs to metals themſelves. Many bodies retain a conſiderable quantity of heat fixed, although they have never been expoſed to the fire, as we have already ſhewn in the inſtance of lapis calaminaris (*i*).

(E) The calxes of metals are deficient in that quantity of phlogiſton which is neceſſary to their metallic ſtate, but yet are not entirely without it; therefore in their ſolution ſcarce any elaſtic fluids are generated, unleſs the fire be continued after exſiccation; ſuch as contain aerial acid diſcharge it imme-

(*i*) Treatiſe on the Ores of Zinc, § IX. H.

 diately

diately in the ſame form as they had received it. It is remarkable, that Dr. Prieſtley mentions a calx of lead which, with the acid of phoſphorus, produced an inflammable air. By means of the nitrous acid, and evaporation to dryneſs, a pure air is produced, partly by the decompoſition of the matter of heat, and partly by the phlogiſtication of the nitrous air; for metallic calxes, and ſeveral other earthy matters, attract the nitrous acid, and fix it to a certain degree, ſo that it can be loaded with the phlogiſton of the heat; during which operation the pure air, which is the other principle of heat, is ſet at liberty, and at length a like air is generated from the nitrous air. Pure nitre, urged by fire, illuſtrates this proceſs very well. If nitre be kept red hot upon a tile for half an hour, and upon cooling vinegar be added, or even a weaker acid, immediately the phlogiſticated nitrous acid is diſcovered by its ſmell; but from whence can this phlogiſtication be deduced, only from the heat paſſing through? Beſides, by a long continued fire, all the acid is expelled; but a very ſmall quantity of it may be collected in a recipient adapted for the purpoſe; and in the mean time, by means of a pneumatic apparatus, air of different degrees of goodneſs may be had in great plenty.—Does not this manifeſtly indicate ſucceſſive changes taking place in the acid?

Some-

Sometimes a ſmall portion of vitriolic air is had, by means of a proper degree of fire, from vitriolic acid, but a far greater quantity of pure air, occaſioned by the decompoſition of the heat.

(F) The ſolution made by the menſtrua above mentioned contains a metallic calx intimately united with the acid; but the quantity of phlogiſton remaining varies, according to the difference of the menſtrua, and of the temperature. The operation being performed, either with or without an intenſe heat, frequently occaſions a notable difference, as we have already obſerved in the inſtance of (*k*) nitrated mercury. That calcination is effected more gently by the marine than by the nitrous acid, will eaſily appear on pouring concentrated nitrous acid on tin or antimony; the difference is not ſo viſible in the other metals, if it actually does take place.

As the neceſſity of this calcination, during the ſolution of metals, has been thought by ſome modern chemiſts not only doubtful but even falſe, let us here conſider ſeparately, but briefly, the caſe of the perfect metals, which they inſiſt ought to be excepted, as they do not yield to the moſt intenſe fire. Let us therefore obſerve, 1ſt, that during their ſolution nitrous air is always generated, and of a very perfect kind; this

(*k*) Vol. i. p. 132.

cannot

cannot arife without phlogifton, but in this cafe there is nothing prefent which can yield phlogifton, except the metals: therefore, 2d, the metals, when precipitated from the menftrua by fixed alkalis, both with refpect to their external appearance and internal properties, appear to be calcined; *v. g.* the precipitate of gold rejects mercury, is diffolved in marine acid, and other fimple menftrua, and that without the production of any elaftic fluid. 3d, Glafs may be ftained by thefe metals; but no metal in its complete form can be taken up by glafs, much lefs ferve to ftain it.

The vulgar objection arifes from hence, that the calxes of the perfect metals may be reduced folely by means of a fufficient degree of fire, without the addition of charcoal; but this depends upon the great force with which thefe calxes attract phlogifton, fo that they are able to decompofe the matter of heat, and to take away and retain as much of that principle as is fufficient to give them the metallic form; and it is for this reafon that they refift the effect of fire fo obftinately, when in their metallic ftate; for when any phlogifton is taken away, it is inftantly replaced. The calxes even of the imperfect metals attack phlogifton, but are not able to retain a fufficient quantity. Mercury is a fort of intermediate fubftance, as it may, like the imperfect metals, be calcined by fire alone, though with much difficulty,

ficulty, and yet, like the perfect, it can from heat alone receive phlogiſton to ſaturation.

The following has been propoſed to me as an inextricable dilemma: "*Silver cannot*
"*amalgamate with mercury, except when in*
"*its metallic ſtate, yet both ſalited and ni-*
"*trated ſilver are taken up by mercury; it*
"*is therefore not calcined by the acids, but*
"*adheres to them in its metallic form.*" We ſhall not need any aſſiſtance from the higher chemiſtry, in order to ſolve this. It is well known that the calx of copper, diſſolved in vitriolic acid, is precipitated in its metallic form on the addition of iron, and that by means of a double elective attraction; for the iron diſſolving in the acid would form an inflammable air by its phlogiſton, were not the copper preſent, which takes it up, and thereby becomes inſoluble ſo long as it retains it: but from the table of elective attractions it appears that mercury poſſeſſes a ſtronger attraction for acids than ſilver does; if therefore ſalited or nitrated ſilver be triturated with mercury, the ſilver muſt be precipitated in a metallic, and the mercury calcined be diſſolved. This alſo takes place, provided there be moiſture ſufficient to ſuffer the elective attractions to operate; the ſuperabundant mercury greedily takes up the comminuted ſilver precipitate, and the arbores Dianæ are nothing more than ſuch an amalgam cryſtallized. Upon this head

head we ſhall ſay more (§ IV.) ; the fundamental objection is therefore, I hope, removed. But although the acids cannot take up any metal, while it retains its full proportion of phlogiſton, yet various metallic ſalts are able to effect that ſolution ; thus nitrated or ſalited mercury boiled in water, together with the crude metal, can take up a certain proportion of it, without dephlogiſtication ; and the latter of theſe two ſalts by this method, even in the via ſicca, becomes a mercurius dulcis, which contains at the ſame time a crude and a (*l*) calcined mercury.

Perfect ſolutions ſhould in general be tranſparent, and ſome are alſo diſtinguiſhed by a peculiar colour, namely, that colour which is proper to the calx, only rendered more vivid by the moiſture. Thus ſolutions of gold and platina are yellow, thoſe of copper blue or green, thoſe of nickel of a bright green, thoſe of cobalt are red, although the calx is black ; we may obſerve that even this red colour may be heightened to blackneſs ; iron, moderately calcined, is green, but this rarely continues upon further dephlogiſtication. The white calxes of ſilver, lead, tin, biſmuth, arſenic, zinc, antimony, and manganeſe, are diſſolved without colour ; but ſolutions of the lead, tin, and antimony, are ſomewhat yellow, unleſs ſuffi-

(*l*) Acta Stockholm, 1778.

ciently diluted. To this rule mercury forms a ſingular exception, for the orange-coloured calx of this metal is taken up by menſtrua without colour.

That phlogiſton is the chief cauſe of colour, appears alſo from hence, the black calx of manganeſe tinges vitriolic acid with a red colour, but on the addition of ſugar the tinge is entirely (*m*) deſtroyed. Nitrous acid is rendered blue by copper, but when the metal is added in conſiderable quantity, it becomes of a very deep green; the marine acid, which dephlogiſticates the copper leſs, is yet made green, but by dephlegmation may be ſo condenſed as to appear brown. I have ſometimes ſeen a ſolution of ſilver green, although there was not preſent the ſmalleſt particle of copper. This depends upon the abſorption of nitrous air; for let ſmoking nitrous acid be diluted, on the addition of a certain quantity of water it will be of a deep green, by a greater blue, and upon a ſtill greater, becomes limpid; by means of the water the nitrous air is extended to a greater ſpace, and this attenuation, gradually increaſed, varies the colours. From what has been ſaid it readily appears, why nitrous acid is made green by a large quantity of copper.

Metals dephlogiſticated by acid ſolvents powerfully attract phlogiſton; nay, nitrated

(*m*) Of the white Ores of Iron, § VII.

ſilver

ſilver and mercury, and ſalited antimony, corrode animal ſubſtances, in order to extract it. This metallic cauſticity, which is only to be moderated by phlogiſton, ought to be carefully diſtinguiſhed from the acid cauſticity, which is repreſſed by alkalis, and the alkaline, which is mitigated by acids. According to the quantity of phlogiſton preſent, colours vary; and ſome experiments ſhew, that by a ſufficient quantity all colour is entirely deſtroyed, ſomewhat in the ſame way as a white light is generated by the union of the ſeven primitive colours —but of this hereafter.

§ IV. *Different Species of Precipitations.*

Various are the methods by which diſſolved metals may be ſeparated from their menſtrua; and the appearance and nature of thoſe precipitates are occaſionally varied in this operation in a very ſingular manner. — We ſhall mention ſome of the moſt remarkable.

(A) All metals may be precipitated by alkaline ſalts, which by their ſuperior power of attraction ſeparate them from their menſtrua; but the differences of theſe alkalis, with reſpect to their nature and preparation, impreſſes the precipitate with different characters.

With

With the cauſtic fixed alkali the calxes fall almoſt entirely pure, but loaded with water, and the matter of heat which is expelled from the alkalis by the acid. The weight is found to be encreaſed by the water, and perhaps by the matter of heat; but yet leſs than by the aerial acid.

With the aerated fixed alkali, by means of a double decompoſition, the aerial acid unites to moſt calxes. We have already obſerved, that the vegetable alkali, completely aerated, precipitates a white calx from ſalited mercury, but that the mineral alkali does not poſſeſs that (*n*) property.

The volatile alkali, which naturally contains phlogiſton, ſometimes phlogiſticates the precipitates: it throws down a black or white precipitate of mercury; nay, makes the orange-coloured calx white, the reaſon of which phenomenon we ſhall ſoon (*o*) ſee. Gold receives from this precipitant its fulminating quality, as before (*p*) explained.

The alkali, which is commonly called phlogiſticated, generally precipitates metals with an increaſe of weight, as Mr. Macquer firſt demonſtrated.

(B) Frequently the acids occaſion precipitates, and that for different reaſons.

By means of elective attraction, ſilver, mercury, and lead, are taken from the ni-

(*n*) Vol. i. p. 70. (*o*) Vol. i. p. 132.
(*p*) Of the fulminating Calx of Gold.

trous

trous acid, by the addition of the marine or vitriolic. Theſe acids form with the metals new compounds, which are difficult of ſolution in water, they are therefore precipitated in greater or leſſer quantity, according to circumſtances.

By too much dephlogiſtication the nitrous acid can decompound ſalited tin and antimony: for when theſe calxes are too much calcined they reject menſtrua.

(c) Alkalis, ſaturated with acids, which are called neutral ſalts, ſometimes diſturb metallic ſolutions.

By means of a double elective attraction all thoſe which contain vitriolic or marine acid decompoſe ſolutions of ſilver, mercury, or lead, in marine acid, and precipitate the metals.

By forming a triple combination, the vegetable, as well as volatile alkali, although ſaturated with vitriolic, nitrous, or marine acid, precipitate platina from aqua regia. If the mineral alkali forms the baſe, the neutral ſalt has no power of this ſort; — theſe phænomena are more accurately conſidered elſewhere.

(d) Some metallic ſalts can decompoſe others, and precipitate their baſes. This may happen when the acid is different in the two ſalts, or, what is more ſingular, even though it be the ſame.

Solution of gold gives us an example of each

each of these two cases (*q*). This, as is well known, is precipitated by martial vitriol, although the reason, so far as I know, has not been yet explained; but upon examining the precipitate carefully it will be easily understood: for this, when washed and dried, not only shews many resplendent gold-coloured particles, but also unites with mercury by trituration, dissolves in aqua regia, but not in marine acid alone, together with other circumstances which evince a complete resuscitation of the gold. Crystallizable martial vitriol contains phlogiston, but very loosely adhering (*r*), so that the calx of the gold may very easily take it away to supply the loss it had sustained during the solution. That this is the true foundation of the process, appears also from this, that the weight of the dissolved gold is precisely recovered: it is also proved from this circumstance, that dephlogisticated vitriol will not precipitate gold. It may reasonably be enquired why the surrounding aqua regia leaves such a precipitate untouched. The reason is, that the menstruum is diluted and weakened by the quantity of water; for upon boiling it gently, so as to expel the water, the menstruum recovers its solvent power, and takes up the precipitate.—We come now to the origin of the purple precipitate.

(*q*) Treatise on Platina.
(*r*) Vol. I. p. 137, 387, 392.

That a ſolution of gold in aqua regia ſhould be precipitated by a ſolution of tin, the ſame menſtruum, is of more difficult explanation: — in this caſe, it is the ſame menſtruum that holds the two metals diſſolved; what then is the cauſe of the change? At firſt I imagined that the tin had attracted a ſuperabundance of the acid, and taken it from the gold, which being therefore deſtitute of the proper quantity muſt neceſſarily fall to the bottom: but upon employing a ſolution containing ſuperabundant aqua regia, the ſame precipitate was occaſioned. The cauſe is therefore not to be ſought in the menſtruum: let us examine the precipitate itſelf, and perhaps the knowledge of its properties will unfold the myſtery. Its external appearance ſhews nothing like the metallic ſplendor, but altogether reſembles a calx: it is eaſily found by its weight that it cannot conſiſt entirely of gold; and in fact chemical examination diſcovers a conſiderable quantity of tin. It cannot be diſſolved by the marine acid alone, but, upon the addition of a little nitrous acid, is eaſily taken up: triturated with mercury, it ſcarcely unites with it. Theſe properties ſeem to indicate that the gold has ſo far received phlogiſton as to reſiſt the marine acid, unleſs aided by the nitrous; but its earthy appearance, and its habits with reſpect to mercury, evince that it is not in its complete metallic form.

May not therefore the following explanation be conformable to truth?—The ſolution of tin neceſſary for this operation muſt retain as much phlogiſton as it poſſibly can, conſiſtent with ſolubility. This is dropped into a ſolution of gold very much diluted, by which means the remaining phlogiſton of the tin is more looſened, and is more eaſily attracted by the gold calx, which is thereby brought to a ſtate approximating to completion, ſo that it can no longer be retained by the menſtruum; and the ſame happens to the tin, by means of the dephlogiſtication: they muſt both therefore of conſequence fall to the bottom, mixed intimately together. It is probable that in this caſe, it is the tin which prevents the union with mercury.

(E) Beſides, the metals precipitate one another after a certain order. This order is found to be the ſame in all acid menſtrua, and is mentioned in another place. This precipitation is effected by a double elective attraction (s); for the metal which is to be precipitated, exiſts in the ſolution in a calcined ſtate; but being reduced by the phlogiſton of the precipitant falls to the bottom, while at the ſame time the precipitant being calcined becomes ſoluble: but if the precipitant has been ſo calcined, that a part of it being inſoluble is mixed with the precipitate,

(s) Treatiſe on Elective Attractions.

the metallic ſplendor is wanting, and it puts on an earthy appearance. A pure precipitate is of the ſame weight as the metal had been before the ſolution. The mixed precipitates are leſs frequently met with, yet gold precipitated by tin exhibits one of that ſort.

But many anomalous circumſtances occur in this matter, depending, no doubt, upon accident. The order is indeed conſtant, and never inverted: zinc prevails over iron; iron over lead; lead over tin; tin over copper; copper over ſilver; ſilver over mercury, &c.: yet it ſometimes happens that a metal, which, according to the general rule, precipitates another, in its metallic ſtate, from one menſtrua, precipitates it from another in the form of a calx; and from a third, not at all. Some examples will illuſtrate this:—zinc precipitates iron from marine acid in its metallic ſtate, but from the nitrous only in the form of a calx. Perhaps the phlogiſton of the zinc is not ſufficient to reduce the iron, which in the latter caſe has been much more dephlogiſticated; yet the particles of iron, although they were at firſt metallized, may be again calcined in a menſtruum which is very greedy of phlogiſton. Tin, precipitated from marine acid by lead, appears in a complete form; but is not thrown down from nitrous acid; and from vinegar is precipitated in form of a calx, even by iron and zinc: lead lets fall nothing from

from vinegar upon the addition of iron. Theſe and other anomalies will be expreſsly examined in the doctrine of attractions: it will be ſufficient here to mention that a ſmall exceſs of acid is neceſſary; and that without it no precipitation begins (*t*): but a great ſuperabundance prevents that operation, by again diſſolving the precipitate; beſides, the weights of the precipitates and the diſſolved precipitants do not correſpond.

§ V. *Colours of metallic Precipitates.*

Before we conſider the weights of the different metals, we ſhall ſlightly touch upon the precipitates. I employed the mineral alkali, as the degree of ſaturation of it with aerial acid is more conſtant. When I had occaſion for a cauſtic alkali, I prepared it by a ſmall quantity of burned lime, in a cloſe bottle: the goodneſs of it was proved by its occaſioning no precipitation in lime-water. The preparation of phlogiſticated alkali is deſcribed in another place (*u*).

(A) Gold diſſolved in aqua regia is precipitated by cauſtic mineral alkali, almoſt black; by the aerated, yellow; as alſo by the phlogiſticated, unleſs ſome iron be preſent, which frequently happens. As the whole of the gold is ſcarcely ever preci-

(*t*) This was firſt obſerved by the celebrated Gahn.
(*u*) Treatiſe on the humid Art of Aſſaying, § II.

pitated, I cannot pretend to aſcertain the weights.

(B) Neither the cauſtic nor aerated mineral alkali precipitate one half of platina, diſſolved in aqua regia; the precipitate is of an orange colour, which on drying changes to a brown. An over proportion of alkali re-diſſolves the precipitate with a more obſcure tinge; nay, the precipitation is ſo imperfect, that alkali ſaturated with acid ſeems to diſſolve it. The phlogiſticated alkali does not precipitate the depurated ſolution, nor even make it turbid; but heightens the colour in the ſame manner as the exceſs of alkali does.

(C) Silver diſſolved in nitrous acid is precipitated white by aerated mineral alkali; by the cauſtic brown; and by the phlogiſticated alkali of an obſcure yellow; by the nitrous as well as the marine acid, white; but the former precipitate conſiſts of more diſtinct particles, which grow black more ſlowly in the light of the ſun.

(D) Salited mercury is precipitated red, or rather ferruginous, by aerated alkali; by the cauſtic more yellowiſh, or orange. Nitrated mercury, prepared without heat, yields a ferruginous precipitate with mineral alkali; a black with cauſtic: when prepared with heat, it yields to cauſtic alkali an orange, or reddiſh yellow precipitate: by phlogiſticated alkali it is precipitated from all acids, white; which, when dried, becomes

of

of a browniſh yellow. Salited mercury is very ſparingly precipitated by this alkali. The precipitate occaſioned by phlogiſticated alkali is again diſſolved if too much alkali be uſed.

We have before ſhewn that a white precipitate may be obtained by aerated vegetable alkali, and have explained the cauſe.

Corroſive ſublimate muſt be very cautiouſly precipitated by cauſtic, as well as aerated fixed alkali; for the part ſeparated may again be diſſolved by a large quantity of water. If too much alkali be uſed, a new compound ariſes of a peculiar nature.

(E) Nitrated lead is thrown down white by aerated, cauſtic, or phlogiſticated alkali. If too much alkali be uſed, the laſt precipitate is diſſolved with a browniſh yellow colour. Vitriolated and ſalited lead is precipitated white.

(F) Nitrated copper, which ſolution is blue, is precipitated of a bright green by aerated fixed alkali; by the cauſtic, of a greyiſh brown, which grows reddiſh by age. By phlogiſticated alkali, copper is precipitated of a greeniſh colour, which afterwards grows of a browniſh red, and upon exſiccation almoſt black. The aerial acid readily takes up a ſmall portion of copper during the precipitation, which is again depoſited by the heat of boiling.

(G) Iron is precipitated green by the aerated fixed alkali, from vitriolic and marine acid; this precipitate becomes of a browniſh yellow, eſpecially on exſiccation: with the cauſtic alkali it approaches more to black: in the precipitation ſome part is held in ſolution by the aerial acid, if the aerated alkali be uſed: the phlogiſticated alkali yields a dark blue precipitate.

(H) Tin is precipitated white by every alkaline ſalt, even by the phlogiſticated alkali; but at length ſome blue particles, which are mixed, appear, ſo that the whole, when collected and dried, is of a light blue colour. That theſe blue particles depend upon iron is eaſily ſeen upon calcination, for they become ferruginous, and obey the magnet. I have always found in tin an admixture of iron.

(I) Biſmuth is precipitated white by water and alkalis, particularly the former; phlogiſticated alkali throws down a yellow powder, which being mixed with blue particles, occaſioned by iron, at length appears green. This yellow ſediment eaſily diſſolves in nitrous acid.

(K) Nickel is precipitated of a whitiſh green by fixed alkalis; by the phlogiſticated alkali of a yellow; and by exſiccation it is condenſed into a dark brown maſs.

(L) Arſenic diſſolved in acids, which prevent too great dephlogiſtication, may, to a certain degree, be precipitated white by the fixed alkali, even when phlogiſticated, but the ſediment is found ſoluble in water; yet nitrous acid, either alone or joined with the marine,

marine, generally dephlogiſticates the arſenical acid, which thereby becomes unfit for ſeparation. Arſenic, diſſolved in marine acid, with the addition of a little nitrous acid depoſited a white ſediment; upon the addition of a large quantity of phlogiſticated alkali, the ſediment was mixed with Pruſſian blue; this was diſſolved in water, and freed by frequent filtration from the blue particles, and at length, on evaporating to dryneſs, yielded a ſemipellucid maſs.

(M) Cobalt, diſſolved in acids, is thrown down by fixed alkali, whether aerated or cauſtic, of a reddiſh blue, which colour, on exſiccation, grows darker, eſpecially when the former alkali has been uſed: phlogiſticated alkali throws down a powder of almoſt the ſame colour, which, upon exſiccation, becomes of a reddiſh brown.

(N) Zinc is precipitated white by aerated and cauſtic fixed alkali, as alſo by the phlogiſticated alkali; but this laſt, on exſiccation, becomes of a citron colour: a ſmall portion of aerial acid may eaſily eſcape during the precipitation.

(O) Antimony is precipitated white by alkalis, when the phlogiſticated alkali is uſed; at the ſame time almoſt always ſome blue particles are precipitated, although the regulus had been prepared without any iron. The operation ſhould be cautiouſly conducted, leſt ſome part be taken up by the alkaline ſalt.

(P) Man-

(P) Manganeſe, which is procured by reduction from common magneſia nigra, generally renders menſtrua brown, and with aerated alkali yields a yellowiſh brown ſediment; with the cauſtic, one ſtill darker; with the phlogiſticated, a powder is ſeparated, at firſt a blue one, then a white, the mixture of which renders the maſs a darkiſh or rather a black green. That the calx of the manganeſe may be obtained pure and white, the precipitate occaſioned by cauſtic alkali muſt be diſſolved in pure vinegar; for there ſtill remains a quantity of undiſſolved iron, which is taken up by the aerial acid. This acetous ſolution contains little or nothing of iron. That metal may alſo at firſt be ſeparated by a ſmall quantity of volatile alkali.

The common ſolution of the regulus is not perfectly precipitated by aerated alkali; and, upon the remaining liquor ſpontaneouſly evaporating to dryneſs, upon the glaſs are depoſited grains of a metallic ſplendor, and not unlike copper. Theſe are readily, though but partially, diſſolved in nitrous acid; but upon the addition of zinc, nothing but the manganeſe falls, though at firſt it is a little reddiſh. With phlogiſticated alkali, a yellow precipitate, like pure manganeſe, falls, provided the ſolution has depoſited the iron when too much dephlogiſticated by age; but the new ſolution yields a precipitate almoſt like that which is is obtained from common regulus. The yellow ſediment may be diſſolved in water.

There is always a conſiderable difficulty attends the deſcribing of colours, as the ſeveral varieties, which are almoſt innumerable, are deſtitute of particular names. Colours are indeed ſubject to changes, but not the ſmalleſt ever occurs without ſome determinate cauſe; they ſhould therefore be carefully obſerved, for from thence we ſhall always learn ſomething, provided we conſider every thing with due attention.

§ VI. *Nature and Compoſition of Metallic Precipitates.*

The metallic precipitates will reveal to us many myſteries upon proper examination.

(A) Our firſt inquiry ſhall be concerning their weight. I have as yet only examined thoſe precipitates which are occaſioned by aerated mineral alkali, cauſtic alkali, and phlogiſticated alkali. The reſults of many of thoſe experiments I have been obliged to reject, as being too vague and indeterminate; the reſt I hope are ſomewhat better founded. But upon conſidering how difficult it is to depurate and waſh completely the metallic ſediment, ſo that neither the alkali, the aerial acid, the water, nor any other extraneous matter ſhall adhere, I conſider them only as collections of the firſt terms of infinite ſeries,

ſeries, which converge very quickly.—In order to obtain the neareſt poſſible approximation, I repeated the experiments frequently in the moſt accurate manner, and they are here ſubjoined. In the following table 100 parts of the metallic regulus are always ſuppoſed diſſolved.

100 parts

				Dry Precip.
100 parts of Gold, precipitated by	aerated mineral alkali	—	yielded	106
——— ——— ———	cauſtic	——— ———	—	110
——— ——— ———	phlogiſticated	— —	—	—
——— ——— ———	martial vitriol	———	—	100
——— Platina, ———	aerated mineral alkali	———	—	34
——— ——— ———	cauſtic	— —	—	36
——— ——— ———	phlogiſticated	— —	—	—
——— Silver, ———	aerated mineral alkali	———	—	129
——— ——— ———	cauſtic	——— ———	—	112
——— ——— ———	phlogiſticated	———	—	145
——— ——— ———	ſalited	——— ———	—	133
——— ——— ———	vitriolated	— ———	—	134
——— Mercury, ———	aerated mineral alkali	———	—	110
——— ——— ———	cauſtic	——— ———	—	104
——— ——— ———	phlogiſticated	— —	—	—
——— ——— ———	vitriolated	——— ———	—	119

				Dry Precip.
100 parts of Lead,	precipitated by	aerated mineral alkali	yielded	132
—	—	caustic	—	116
—	—	phlogisticated	—	—
—	—	vitriolated	—	143
Copper,	—	aerated mineral alkali	—	194
—	—	caustic	—	158
—	—	phlogisticated	—	530
Iron,	—	aerated mineral alkali	—	225
—	—	caustic	—	170
—	—	phlogisticated	—	590
Tin,	—	aerated mineral alkali	—	131
—	—	caustic	—	130
—	—	phlogisticated	—	250
Bismuth,	—	aerated mineral alkali	—	130
—	—	caustic	—	125
—	—	phlogisticated	—	180
—	—	pure water	—	113

Nickel,	aerated mineral alkali	135
	caustic	128
	phlogisticated	250
Arsenic,	aerated mineral alkali	—
	caustic	—
	phlogisticated	180
Cobalt,	aerated mineral alkali	160
	caustic	140
	phlogisticated	142
Zinc,	aerated mineral alkali	193
	caustic	161
	phlogisticated	495
Antimony,	aerated mineral alkali	140
	caustic	138
	phlogisticated	138
Manganese,	aerated mineral alkali	180
	caustic	168
	phlogisticated	150

(B) Upon

(B) Upon comparing these weights, a question at first occurs concerning the cause of such enormous differences; and it is plain that this cause must be sought for in the precipitates themselves. The fixed alkali, saturated with aerial acid, when added to the solution, is taken up by the more powerful menstruum, and the weaker is of course expelled, and is absorbed by the calx, as it falls in greater or lesser quantity, according to circumstances. That this is actually the case is easily demonstrated:—let a bottle, containing a sufficient quantity of nitrous acid, be accurately weighed; let there be put into it by degrees, *e.g.* 132 parts of lead, precipitated by aerated alkali, and not only an effervescence will be observed, which continues until the very last particle is dissolved; but when the solution is finished a deficiency of weight is discovered, which amounts nearly to 21, and which is indubitably owing to the extrication of aerial acid (§ III. E). But 132 — 21 = 111, a weight which still considerably exceeds that of the metal. Upon distillation nearly 8 of water are discovered; there yet remain therefore 3, which by violent heat are increased by 7; for 132 of the calx, well calcined, yield 110. The whole increment of weight then does not depend upon the water and aerial acid. The same thing is evinced from the consideration of the precipitate of lead by the caustic alkali, as it is evident that in this case there is is no aerial acid; besides, no effervescence accompanies the solution. If we suppose the quantity of water equal in both cases, yet, even on this supposition, the whole excess is not accounted for, for 116 — 8 = 108. It is therefore probable that the matter of heat is attached to the calx. This matter of heat is always present in caustic alkali; for when it is dissolved in the simple acids, heat is always generated. This opinion is confirmed by the following considerations: 1st. The increment of weight can scarce be conceived, without supposing an increment of matter. 2d. When the caustic alkali is employed no other matter can be suspected. 3d. The same cause is also present when the weight is increased by dry calcination. 4th. Let the heat occasioned by the mixture of determinate portions of any acid and caustic alkali be marked upon a thermometer: let then an equal quantity of the same menstruum be saturated with a metal; afterwards, upon the addition of an equal quantity of caustic alkali, it will be found either that no heat is generated, or a degree very much less than before. Some of the matter of heat therefore is taken up and fixed, which also generally makes the colours of the precipitates more obscure, and in distillation with sal ammoniac communicates to the volatile alkali the quantity that had been taken away. What has been said of lead is also true of the other metals, a few excepted,

 which

which ſeem to take up little or no aerial acid; theſe are tin, antimony, gold, and platina.

(c) But ſome precipitates *retain alſo a quantity of the menſtruum.* Thus, corroſive ſublimate, precipitated by aerated alkali, retains a portion of marine acid, which cannot be waſhed off by water; but by cauſtic alkali the precipitate may be obtained, either free of the acid altogether, or in a great meaſure. In this caſe, as in many others, the aerial acid ſeems to generate a triple ſalt, which is ſcarcely ſoluble. The preſence of the marine acid is eaſily diſcovered by nitrated ſilver, if the precipitate be previouſly diſſolved in pure nitrous acid. Hence we obſerve another difference in mercury precipitated from marine acid, according as aerated or cauſtic alkali has been employed: the latter precipitate, well waſhed and put into volatile alkali, is ſcarcely changed in colour; but the former inſtantly grows white, generating a ſpecies of ſal alembroth, but containing ſo litle marine acid as not to be eaſily ſoluble in water.

The calxes, which retain any of their former menſtruum, generally give over on diſtillation a ſmall portion of a ſublimate. The mercurial calx, juſt mentioned, expoſed to a ſufficient degree of heat, is partly reduced to crude mercury, partly to mercurius dulcis, by means of its remaining marine acid. This mercurius dulcis did not exiſt in the

 precipitate;

precipitate; for in that caſe it would be eaſily diſcovered by acids, in which it is not ſoluble, and would grow black with cauſtic alkali, neither of which things takes place; it is therefore generated during the diſtillation.

(D) The nature of phlogiſticated alkali is as yet obſcure, but it poſſeſſes the ſame properties, with regard to ſalts and alkaline earths, as acids when loaded with phlogiſton do:—the ſame is true with regard to metallic calxes, with which it forms compounds of a ſaline nature, though moſt of them are inſoluble in water.

§ VII. *Advantages reſulting from the Examination of metallic Precipitates.*

In order to recommend the more accurate examination of metallic precipitates, I beg leave to add a few words concerning the advantages to be derived from that labour.

(A) It is evident that by more intimate acquaintance with theſe precipitates, the chemical theory of the operation will be better underſtood.

(B) We may thereby be able to diſcover the more uſeful and remarkable properties. No one is ignorant that aurum fulminans, the mineral purple, and other encauſtic pigments, by which the colours of gems may be imitated, have been derived from this ſource.

(c) A foundation is thereby laid for the art of aſſaying by the humid way, from the bare knowledge of the weights. It may be objected, that the doctrine of the weights is very fallacious; that they vary in the different precipitates; that by imperfect precipitation ſomething remains in the liquor; and that ſometimes extraneous matters are mixed with them. All this is true; but if the mode of operation be always the ſame, the reſults of the experiments will be conſtant. Let us ſuppoſe that a quantity of metal (a), precipitated in a certain manner, makes a weight (b); if that ſame manner be exactly employed, we may fairly conclude that a quantity of precipitate (n b), occurring in any caſe, is correſpondent to a quantity of perfect metal (n a), although in the fundamental experiment either the precipitation is incomplete, or ſome extraneous matter be preſent. If all the circumſtances which occaſion increaſe or deficiency be carefully attended to, the concluſion will remain unimpeached: let the method therefore be accurately determined, and there will be no danger of fallacy.

(D) By this the nature of metals is illuſtrated. Platina, nickel, cobalt, and manganeſe, are ſuſpected by ſome perſons to derive their origin from a mixture of other metals. But if iron neceſſarily enters into the compoſition of platina, when this is diſſolved in aqua regia it ſhould produce a Pruſſian blue

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upon the addition of phlogiſticated alkali; and this is the caſe in fact when common platina is employed, but not when it is rightly depurated (*w*).

If iron, adhering very obſtinately to nickel, formed a great part of it, the precipitates obtained from it by alkalis could not differ from martial precipitates ſo much as they do, in colour, weight, and other properties.

The ſame is true of cobalt and manganeſe. The regulus obtained from magneſia nigra contains about 0,08 of iron: let us ſee how this affects the mixture.

100 diſſolved in an acid menſtruum yields to phlogiſticated alkali a powder, conſiſting partly of blue, partly of browniſh yellow particles, which is equal in weight to 150 lb.; but 8 lb. of iron yield 48 of Pruſſian blue, nearly $\frac{1}{3}$ of the whole maſs: hence it follows, that 100 parts of pure manganeſe yield to phlogiſticated alkali ſcarcely 111, *i. e.* nearly ſix times leſs than an equal weight of iron.

(E) Finally, it may by this means perhaps be poſſible to determine the unequal quantities of phlogiſton in different metals; for a given weight of precipitating metal does not yield an equal quantity of precipitate: thus, *e. g.* copper is able to precipitate from nitrous acid four times its own weight of ſilver.

(*w*) Treatiſe on Platina, § VII. (G).

DISSERTATION XXIV.

OF THE ART OF ASSAYING IN THE HUMID WAY.

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§ 1. *Circumſtances attending aſſaying by the dry Way.*

THERE is no doubt but ores were dug up, and their metallic contents extracted, long before the invention of the docimaſtic art; but the ſuperior induſtry of later times has diſcovered the neceſſity of making trials in ſmall, by which the quality and goodneſs of the ore being previouſly known, unneceſſary expence may often be timely guarded againſt; and, as the great works are effected by means of fire, it was thought

thought proper to employ the ſame agent in the leſſer experiments. The firſt attempts certainly were extremely rude, but repeated and collected trials have gradually advanced it to the form of a ſcience, or rather of an art, which although, no doubt, long concealed in the laboratory, was not publiſhed until the middle of the 16th century. The firſt book upon this ſubject is generally attributed to Lazarus Ercker; this was publiſhed in 1574. But Agricola, in his ſeventh Book de re Metallica, publiſhed in 1576, deſcribed both the inſtruments and the proceſſes, and illuſtrated them with plates. And from the preface to the Ars Docimaſtica of Modeſtinus Fachs, it evidently appears, that the manuſcript had been preſented, in the month of March 1567, to the elector of Saxony, though it was not publiſhed until after Ercker's book. In proceſs of time this art became far more perfect; but we have not leiſure to purſue it through its ſucceſſive ſtates of improvement.

In the docimaſia ſicca three circumſtances are neceſſarily required;—1. *That the metal contained in the ore be all reduced to a complete form*; for ſuch part of it as is deficient in that reſpect, cannot be united with the eliquated metal. 2. *That the ſame be collected into one maſs*; for when it is in the form of numerous ſmall grains, ſome of them are very eaſily ſcattered, and diminiſh

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the weight. 3. *That the metallic form once induced be preserved*; for the extracted regulus must inevitably be diminished more or less by calcination.

All these requisites are frequently effected commodiously and perfectly enough by fusion in a crucible with proper strata of charcoal, provided the ore is free from sulphur, and every other volatile mixture, and is either entirely without a matrix, or united to one which is fusible by a moderate degree of heat; but if the matrix be refractory, notwithstanding the most subtile pulverization it will cover many metallic particles, and thus prevent their reduction and fusion. In this case it is necessary to employ such additaments as not only promote fusion, but occasion such a degree of tenuity as may suffer the reguline particles to fall to the bottom. To this they are naturally disposed by their great specific gravity; but, nevertheless, if the mass be tenacious or thick, and especially if they themselves be small and discrete, they are kept floating by the great friction which is to be overcome in their descent. These additaments, which from their effect are called fluxes, are of a saline nature, and must therefore necessarily corrode the metals more or less; and hence the scoriæ, which are almost always tinged, contain a quantity of calcined metal.

But, *so long as we are destitute of a sure method of measuring intense degrees of heat, and*

and ſo long as it is neceſſary to perform the operation in cloſe veſſels, to prevent the acceſs of air, ſo long will the force and proper continuance of the fire be, as it has hitherto been, uncertain. Now, by every exceſs or defect in this point, ſomewhat of the regulus is loſt; ſo that any judgment of the goodneſs of the ore, formed from the weight of the regulus, muſt be fallacious and uncertain, or at leaſt ſomewhat inaccurate.

All this ſufficiently ſhews, that experiments made in the dry way are ſtill liable to many faults and imperfections; to which we may add ſome more; *viz.*—Any given quantity of ore, ſubjected to trial, almoſt always exceeds the regulus to be extracted from it very much in weight. Now, ſince it is almoſt impoſſible to avoid a certain loſs during both calcination and fuſion, this loſs will be the more remarkable as the maſs ultimately to be weighed becomes lighter. The caſe is quite otherwiſe with experiments made in the humid way; for here the weight of ſediment, from which the quantity of the content is judged, is never leſs, but often greater, than that obtained by fire. Let the loſs ſuſtained in examining equal quantities of ore in both ways be the ſame, and denoted by (n); let the quantity of regulus, obtained by fire, be expreſſed by (a); that of the ſediment collected in the humid way by (m a); and the true value of of the regulus will be a $+$ n. This being ſuppoſed, as (m) is never leſs than unity, it is obvious, that, except in caſe of equality, $n : a > n : m\,a$; and, beſides, that (n) is the more diminiſhed in reſpect to (m a) in proportion as (m) exceeds unity the more. The examples occurring hereafter will illuſtrate this truth more at large.

§ 11. *General Obſervations to be made in conducting the Proceſs of aſſaying by the Via Humida.*

Chemiſtry has at length begun to examine the compoſition of ores by means of various menſtrua; yet it muſt be confeſſed, that the fragments of the humid art of aſſaying, which have hitherto been publiſhed, are rather to be conſidered as inſtances of a mixed method, in which the mineral analyſis is accompliſhed partly by the dry, partly by the humid method. The metallic part is indeed extracted by a menſtruum, but is afterwards reduced by fire. In the following pages, however, I ſhall endeavour to point out means by which the end may be anſwered in the humid way alone, without calcination or fuſion. — It is by no means my intention to depreciate the dry way. In practice, the moſt commodious and moſt accurate proceſſes ought always to prevail; but a due compariſon of theſe two methods can never be inſtituted, nor the beſt

beſt methods of operation choſen, ſo long as either remains clogged with difficulties and impediments. In the proſecution of mineral analyſis, it is therefore of the higheſt moment to remove theſe difficulties; for the docimaſia ſicca conceals and confounds many of the heterogeneous admixtures; and if, by means of the humid way, theſe can be all ſegregated and determined as to quantity and quality, not only much light will be thrown on mineralogy and metallurgy, but the true foundations of theſe ſciences laid, as any perſon who is not entirely ignorant of them may readily perceive. Very often it is uſeful to know, not only the heterogeneous metallic ſubſtances, which ſometimes, to the amount of three or four, are mixed with the extracted regulus, but frequently, alſo, the occult earthy matrix; and yet neither of theſe can be accurately diſcovered, except in a very few caſes, by the dry method, as it has hitherto been practiſed; for it is evident, that in fuſed maſſes the admixtures which ought to be removed, are the better protected by the genuine materials in proportion as the former are more diminiſhed; a circumſtance which cannot take place in ſolutions, which may be diluted *ad libitum*. It muſt indeed be confeſſed, that experiments in the humid way often require more time, more care and pains; but if accurate concluſions are thereby ſupplied, we ſhould not be difficult

about

about ſlowneſs. Beſides, in many caſes this method is more expeditious than the other; and that indeed almoſt always, if we are content with ſuch diſcoveries as can be made by the common calcinations and fuſions; nay, ſometimes the dry method is obviouſly inſufficient, when the metallic content is either very ſmall or volatile, but particularly if it be inflammable, as is the caſe with zinc.

In the following experiments an aſſay cwt. was always employed, unleſs where it is expreſsly mentioned otherwiſe. Concluſions ſufficiently accurate may indeed be often obtained from 25 lb. nay ſometimes from ſmaller quantities. In theſe caſes I have mentioned the uſual quantity, applying to them thoſe formulæ of calculation which are founded on the mutual proportions of the proximate principles conſtituting metallic ſalts, and which are determined in another place (*a*) from the weights of metallic precipitates. By an eaſy ſubſtitution the ſame formulæ may be uſed by thoſe who employ ¼ or ½ cwt.

The ores to be examined ſhould be reduced to a very ſubtile powder by pulverization and elutriation.

The ſolutions of ſuch ores as contain ſulphur require much caution: if poſſible, the

(*a*) See the Treatiſe on the Analyſis of Waters, § XI and this Treatiſe, § VI.

the vitriolic or marine acid ſhould be employed; for by continued heat the nitrous acid deſtroys the ſulphur: by too violent an heat, alſo, ſome of it is diſſipated in vapours, or is melted into globules containing heterogeneous matters; therefore, if it can be done, boiling ſhould be avoided.

All the precipitates muſt carefully be waſhed, collected, dried, and weighed, as is obvious. It is ſufficient here to mention this, to avoid the trouble of repetition. Diſtilled water ſhould conſtantly be uſed, and all the menſtrua carefully depurated. I call vitriolic acid diluted when its ſpecific gravity is below 1,3; nitrous, when below 1,2; and the marine, when below 1,1.

The precipitations ſhould be carefully made (in glaſs veſſels), ſo that neither by the deficiency of the precipitant ſhall any thing remain in the menſtruum, nor by its abundance any thing be re-diſſolved. The clear liquor is to be decanted from the ſediment, water poured on in its place, the veſſel ſhaken, and then ſuffered to ſtand; the water again decanted off, and freſh poured on, until it no longer can affect certain precipitants by which it muſt be examined.

This being done, the ſediment is to be collected upon a filter (firſt weighed) made of paper not impregnated with alum, dried at firſt with a gentle heat, but after expoſed for five minutes in a cloſe glaſs veſſel to 100° of heat; upon cooling it is to be weighed, together

gether with the filter, the known weight of which muſt afterwards be ſubducted. The beſt method of waſhing the ſediment is in a bottle; for the filter, when once filled with a ſaline ſolution, is not without great difficulty freed from it, eſpecially if there intervenes a delay of ſome hours.

When I ſpeak of an alkaline precipitant, the mineral alkali, charged to ſaturation with aerial acid, is always to be underſtood.

The alkali, which is commonly called phlogiſticated, I always prepared in the ſame way — equal weights of the pureſt nitre and cream of tartar, well pulverized and mixed, are heated in the uſual way and detonated. The common white flux is thus procured :—half an ounce of this is diſſolved in a cucurbit, in half a quadrans of diſtilled water; then in a digeſting heat are gradually added two ounces of Pruſſian blue, carefully avoiding ſuch an effervеſcence of the liquor as may throw any thing over, which eaſily happens if the quantity be too large: the pigment ſoon loſes its beautiful colour, not growing red but black, which evidently ſhews that a complete decompoſition has not taken place. The Pruſſian blue for ſale, is not always found of the ſame quality. That which was uſed in the following experiment, contained in 100 parts 77 of clay, and only 23 of the pigment; ſo that if it be thought proper to employ the blue made without any alum, 221 grains will

will ſaturate the half ounce of alkaline ſalt more completely than the two ounces above preſcribed, and the bulk of the reſiduum is thereby alſo leſſened. Whatever way the operation be performed, after the addition of the laſt portion the whole muſt be expoſed to a ſtronger digeſting heat, and the maſs often ſtirred with a wooden rod: if the liquor be too much diminiſhed by evaporation the defect muſt be ſupplied by warm water. At length the lixivium becoming clear, let the reſiduum be collected on a filtering paper, and gradually waſhed with warm water until all the ſoluble part is ſeparated. If the operation be rightly conducted, the clear liquor amounts to an whole quadrans, of a browniſh yellow, and ſo ſaturated as not to make paper tinged by Brazil wood blue; hence the colouring principle united to the alkaline ſalt ſeems to be of an acid nature; but the Pruſſian blue, and other metallic precipitates of the ſame kind, always yield on diſtillation, beſides an unctuous matter, a diſtinct volatile alkali.

The lixivium ſaturated with the colouring matter contains alſo a ſmall portion of perfect Pruſſian blue, about 4 lb. to a cwt. of the alkaline ſalt; which are ſeparated on the addition of the acid: theſe ſhould be previouſly ſeparated, or, what is better, corrected, by ſubducting from the weight of the ſediment 16 aſſay pounds for each quadrans of the lixivium. When the queſtion is about a diſtinct

ſtinct colour in the precipitate, the lixivium muſt neceſſarily be employed well depurated: thoſe who neglect this precaution, readily perſuade themſelves that any metal, precipitated by our lixivium, can put on the blue colour. But if the queſtion be only about the weight, let the lixivium, ſtill loaded with a ſmall portion of Pruſſian blue, be dropped; however, the proper correction muſt ultimately be employed; for the precipitating acid, in a ſhort time, is wont alſo to weaken the properties of the lixivium, and even to deſtroy them, eſpecially in a warm temperature. Lime, whether aerated or cauſtic, is alſo capable of abſtracting a colouring ſubſtance from iron and other metals. We ſhall perhaps ſpeak in another place more at large of the qualities and properties of theſe combinations, here we only treat of their preparation and uſe.

In the precipitating of metals by metals, it is to be obſerved, that the acid of the ſolution ought to be ſomewhat predominant; but any more conſiderable exceſs muſt be corrected occaſionally, either by alkali, water, or ſpirit of wine.

§ III. *Ores of Gold.*

Gold occurs in the bowels of the earth native, poſſeſſing a compleat metallic form, although in general the ſmall particles of it

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are so interspersed in various matrices, that they are entirely invisible; it is also found mineralized, that is, united with sulphur, by means of iron, or some other metal. These two species of ore we shall consider separately.

(A) Native gold is very seldom, if ever, entirely free from heterogeneous matters; the most usual inquinaments are copper, silver, and sometimes iron. The first of these remains in the menstruum, and may be separately collected, if the gold be dissolved in aqua regia, and precipitated by martial vitriol (§ VIII.); the second falls during the solution, yielding a salited silver, which, washed and dried, shews the weight of the silver contained (§ V.); finally, the last is discovered by a phlogisticated alkali, and is estimated in a manner elsewhere described (§ IX.). The precipitate occasioned by the martial vitriol is pure gold in its metallic form, although very subtilely divided; and therefore the weight found requires no correction.

From the preceding and following circumstances it appears, how a small portion of gold, inhering in the ores of other metals, may be extracted; besides, a solution, containing the most minute particle of gold, instantly produces the purple precipitate of Cassius, with a solution of tin properly prepared.

(B) As to the ore which contains gold adhering to and ſurrounded by ſtony particles, firſt a determined weight is to be reduced to an impalpable powder, by triture and elutriation.

Then let the powder, weighed a ſecond time, be boiled in aqua regia, ſo long as any thing is taken up by the menſtruum; after which let the exhauſted ore, well waſhed, be collected, exſiccated to ignition, and weighed.

Let the clear ſolution (the colour of which in ſome degree affords a method of judging) be precipitated in the uſual way by martial vitriol; the precipitate well waſhed, dried, and weighed, ſhews the gold, which, added to the weight of the exhauſted ore, ought to equal the original weight, unleſs ſomewhat has been diſperſed by the pulverization, or unleſs ſome of the matrix has entered the menſtruum: the former of theſe is diſcovered by comparing the weights before and after pulverization, the latter by precipitants.

When grains of gold are mixed with looſe earthy particles, they are ſometimes eaſily ſeparated by mechanical application of water.

(C) Let one or more aſſay cwts. of the golden pyrites, reduced to powder, be gently boiled in diluted nitrous acid, or rather digeſted in an heat of 50°—80°, leſt the ſulphur ſhould be deſtroyed; a gentler heat even is neceſſary

neceſſary for this purpoſe, that the ſulphureous particles, gradually ſeparating, may remain in their natural ſtate; for if they fuſe, the heterogeneous particles, which ought to be removed, will be included in the fuſed maſs.

This operation muſt be ſo conducted, that the menſtruum may be added in ſeveral portions, at each turn about ſix times the weight of the ore; this attacks the pyrites with an effervefcence, occaſioned by the extrication of a large quantity of nitrous acid. When this effect ceaſes, another portion is to be poured on, until the ſulphur is obtained pure, and marked with its genuine colour. This proceſs generally requires to one part of the ore from 12 to 16 of the acid.

Let the ſulphur, when waſhed, be collected upon a filter, dried, and weighed: whether it be pure or not is eaſily determined by the cauſtic fixed alkali.

If the matrix is inſoluble in the menſtruum, it remains at the bottom, together with the gold, which is diſtinguiſhed by its peculiar ſplendor and colour, and may be ſeparated from the powder of the matrix by careful elutriation. The particles of gold do not aſſume the form of impalpable atoms, but of grains, very ſmall indeed, but ſuch that a diſcerning eye will readily obſerve their angles and inequalities; and their appearance may perhaps lead to a ſuſpicion

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that they have been rather mixed with, than diſſolved by the pyrites.

The clear ſolution is generally green; let this be evaporated to dryneſs, then ignited and weighed. If there be other metals beſides iron preſent, they may be extracted by ſuitable menſtrua; copper by the volatile alkali; manganeſe, which is generally preſent, by dilute nitrous acid, with the addition of a little ſugar; zinc by any menſtruum, although this is ſcarcely ever found in gold pyrites; and ſilver by pure nitrous acid. When calcareous earth forms the matrix, it unites with nitrous acid, and yields a nitrated lime; when clay, it forms an alum with vitriolic acid.

The ſum of the weights of all the ingredients ſhould be equal to the original weight; and, unleſs ſome loſs has been ſuſtained during the operation, any deficiency is to be attributed to the ſulphur deſtroyed.

(D) I have as yet only ſeen one ſpecimen of the ore of Nagyay; this conſiſts of a grey quartz, and a white matter not unlike a ſandy ſtone, which is taken up with efferveſcence by acids, without imparting any tinge to the menſtruum. The ſolution forms, with aerated alkali, a white precipitate, and with phlogiſticated alkali a browniſh yellow. By the dry method the ſame matrix ſoon grows black in the fire,

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and, according to circumſtances, tinges microcoſmic ſalt either with a purple colour, or does not tinge it at all; it is therefore (*b*) an aerated mangancſe. This matrix contains diſperſed in it lamellæ of the colour of lead, or a little darker, which yields to the knife: theſe, with warm aqua regia, grow quickly white, and are totally diſſolved with effervеſcence, tinging the menſtruum yellow; on cooling, the ſolution depoſits acicular cryſtals. If we were provided with a ſufficient quantity of the ore, I have no doubt but its conſtituent principles might be ſeparated in the humid way by proper menſtrua.

§ IV. *Ores of Platina.*

So far as we know, the metal called platina is not found any where but in America, and is always native. The only metal with which this is conſtantly alloyed is iron, the greateſt part of which may be ſeparated by repeatedly boiling the grains of platina, reduced to as fine a powder as poſſible, in marine acid; in this way the original weight is generally diminiſhed about 0,05.

The platina, being thus depurated, and diſſolved in aqua regia, eaſily diſcovers itſelf

(*b*) Treatiſe on the White Ores of Iron, § VII.

by means of martial vitriol, if any gold be preſent: on the other hand, if platina contains a ſmall portion of gold, this may, for the moſt part, be precipitated by any neutral ſalt, containing vegetable or volatile alkali.

§ v. *Ores of Silver.*

Silver, beſides its complete form, puts on in the bowels of the earth a variety of forms, partly united with ſulphur, either alone or with other metals, partly mineralized by acids.

(A) Native ſilver is generally allayed with gold or copper, or both; the ſilver and copper are eaſily taken up by nitrous acid; and if any gold be preſent, it appears at the bottom like a black powder, which by ſolution in aqua regia, and precipitation by martial vitriol, may be made at pleaſure to aſſume a more metallic appearance.

This ſeparation being effected, the copper remaining in the liquor may eaſily be collected by means of iron, or aerated alkali.

There has lately been diſcovered a new variety of ſilver ore, which is extremely rich; this is found in two different places, namely, at Andreaſberg in Hercynia, and at Wittichen in Fuſtenberg; a ſpecimen of each is to be ſeen in the Academy's collection. That of Fuſtenberg has the appearance of of irregular grains conglomerated, which poſſeſs a metallic ſplendor, are a little yellow, and, together with native ſilver, are contained in the common white ſpathum ponderoſum. The grains, when examined, are found to contain ſilver allayed with a ſmall portion of regulus of antimony. Theſe metals may be ſeparated by concentrated nitrous acid; for the firſt is thereby diſſolved, and the latter corroded into a white calx. Aqua regia takes up the antimony, a ſalited ſilver remaining at the bottom. The particles of this ore are ſomewhat malleable, and ſhould be reduced as fine as poſſible before they are put into the menſtruum. The ore of Hercynia is called butyraceous; that which I have ſeen, exhibited, in a calcareous matrix, very thin leaves of metal, the ſcarcity as well as tenuity of which, in the above-mentioned ſpecimen, prevented me from making proper experiments; ſo that I dare not abſolutely affirm that this agrees with the former in its properties, although it appears very probable.

(B) Silver united with ſulphur alone is black, and is commonly called the glaſſy ore of ſilver. Let this, divided and comminuted as much as poſſible, be gently boiled for an hour in 25 cwt. of diluted nitrous acid; the liquor being decanted, let the operation then be repeated with an equal quantity of the menſtruum; and unleſs the pure ſulphur be now ſeparated, the menſtruum is to be employed anew: the laſt particles of the ſilver adhere obſtinately to the ſulphur: if any gold be preſent, it remains undiſſolved at the bottom.

The decanted liquors being collected, are to be deprived of the ſilver by the addition of common ſalt; let this, when collected, waſhed, and dried, be = a, and the ſilver required will $= \frac{100\,a}{129}$.

Let the ſulphur be weighed ſeparately, and its weight, added to the above, ſhould amount to lb. 100, if the operation has been rightly performed, and no decompoſition of the ſulphur has taken place.

The clear liquor which paſſes in filtering the luna cornea, upon the addition of a phlogiſticated alkali quickly diſcovers the foreign metal accidentally inhering in it: and after this precipitation the earthy contents are exhibited by a fixed alkali. The reliquiæ of the inſoluble matrix are with difficulty ſeparated from the ſulphureous particles:—let the ſum of the weights be firſt enquired, then let cauſtic alkaline lixivium be poured on, and the ſulphur diſſolved in a gentle digeſting heat; the matrix then remains alone, and its weight determines that of the ſulphur. The digeſtion muſt not be continued longer than is neceſſary, for the ſiliceous earth is alſo capable of entering the lixivium. However, this inconvenience is not very much to be apprehended, for to this effect

effect the mechanical divifion muft be far more completely performed.

(c) Silver, united to fulphur and arfenic jointly, is generally diftinguifhed by its red colour, fometimes beautifully pellucid, refembling a ruby; but it is fometimes grey, metallic, and opake. All thefe varieties however yield a red powder, and hence it is called the red ore of filver.

Let this, reduced to a very fubtile powder, be twice gently boiled in diluted nitrous acid as above: a part of the menftruum being decanted off, let the white powder which remains at the bottom be well wafhed with diftilled water: let the filver be precipitated from the clear liquors, collected by means of fea-falt; and finally, let the falited fediment, properly treated, be weighed as before.

Let the white powder above mentioned be quickly boiled in a fufficient quantity of aqua regia, until the arfenic be diffolved, and the fulphur appears pure. The yellow folution, cautioufly decanted, lets fall a very white powder, upon the addition of a fuitable portion of water; and the fmall quantity which is taken up by the water is collected by evaporating to drynefs.

The fulphur now feparated, though it appears pure, yet ftill contains a little filver, which could not eafily be feparated before by the nitrous acid, on account of the arfenic: but when the arfenic is taken away by by the aqua regia, the remaining parts of the ſilver are taken up by the marine acid, entangled in ſulphureous particles. In order therefore to free the ſulphur from this ſalited ſilver, let cauſtic volatile alkali, diluted with water, be poured on, and kept in a well-cloſed veſſel for ſome days—a weight of the alkaline liquor equal to that of the ſulphur is ſufficient. The ſulphur being weighed before and after the operation, indicates the weight both of itſelf and of the ſalited ſilver.

If any iron be preſent, which I have ſeldom experienced, it may be diſcovered in the liquors firſt precipitated with the ſalt or water, by means of phlogiſticated alkali.

(D) Silver united with ſulphur, arſenic, and copper, is generally called the white ore of ſilver, and is examined in the following manner:—let 1 cwt. of the ore, reduced to powder, be gently boiled for an hour in a little more than twelve times its weight of diluted nitrous acid. The dry powder grows black and foul; and, when added to the acid, ſends forth an hepatic ſmell, a portion of it is diſſolved, and at length a white reſiduum remains at the bottom: upon ſubſiding, if the liquor cannot be decanted clear, let it be filtered. This liquor contains the ſilver and the copper; the former of theſe cannot be precipitated alone by muria, becauſe the marine acid attracts the copper more ſtrongly. A white precipitate, compoſed

poſed of ſmall aciculæ, is indeed thrown down; but upon expoſure for ſome days to the rays of the ſun, does not grow black in the ſmalleſt degree; and it conſiſts of a peculiar combination of marine acid, ſilver, and copper. The ſilver therefore in this caſe is to be precipitated by a determined weight of copper; and afterwards the copper to be ſeparated by iron or aerated alkali (§ VIII.); but the ultimate weight is to be diminiſhed by that of ſuch part of the precipitant as has entered the menſtruum.

Let the white reſiduum be boiled in marine acid, and precipitated by water; thus we obtain the arſenic with a ſmall portion of marine acid, which yet it retains obſtinately, as is elſewhere obſerved.

The arſenic being ſeparated, the ſulphur remains alone, and muſt be proved by volatile alkali, to try whether it ſtill contains any copper or ſalited ſilver.

(E) Silver mineralized by ſulphur, ſometimes alſo contains antimony: this ore often forms capillary threads of an hoary brown colour: let this be gently boiled, or rather digeſted, for an hour, in ſix times its weight of diluted nitrous acid, until the ſilver is diſſolved, and all the antimony reduced to a white calx, which, after decanting the liquor, may be ſeparated from the ſulphur by marine acid, and precipitated by water. The ſolution of ſilver is to be precipitated

by

by muria, and 1 cwt. ſeldom contains more than four ounces.

(F) Beſides ſulphur and antimony, there is ſometimes alſo preſent copper and iron; but the experiment in this caſe may be conducted in the ſame way, only with a double proportion of acid. Theſe metals all remain in the liquor, but are eaſily ſeparated by precipitating the ſilver, by means of copper; and the iron by zinc, or an alkaline ſalt.

(G) We ſometimes meet with ſilver mineralized by ſulphur at the ſame time containing iron: but in the ore which the Germans call *weiſertz* ſilver is frequently abſent, ſo that the ſilver which is ſometimes diſcovered in it ſeems to be native.

(H) Silver, mineralized by the marine and vitriolic acids, is commonly known by the name of corneous ore of ſilver: the colour of this is white, green, yellow, violet, or black. Two remarkable varieties of it occur, the one may be cut, and is ſomewhat malleable; the other brittle, which, beſides the acid, alſo contains ſulphur.

Let 100 of the former, comminuted as much as poſſible, be plunged into marine acid, and kept for one day in a digeſting heat, ſhaking the mixture from time to time: let the liquor be afterwards decanted clear, and the reſiduum, previouſly well waſhed with water, be added to the liquor: then let nitrated terra ponderoſa be gradually dropped

dropped in, until it ceafes to occafion any precipitation. Suppofe the weight of the precipitate, wafhed and dried, = a; now vitriolated terra ponderofa, whofe weight is a, contains of acid 0,15 a, which correfponds with vitriolated filver 0,48 a; for from 100 of vitriol of filver 68,75 of metal is obtained by reduction. All the filver is not precipitated from nitrous acid by the vitriolated mineral alkali: the falited filver therefore, will be 100 — 0,48 a. In the former falt the filver contained is expreffed by 0,33 a; in the latter by 75,19 — 0,36 a, and therefore the fum required for the 100 will be 75,19 — 0,03 a. Thefe and the following formulæ depend upon the mutual proportion of the principles, and the weights of the precipitates, which are experimentally determined in the Tract on metallic Precipitates (§ VI. A).

The brittle horny ore alfo contains fulphur, but the faline part may be extracted by volatile alkali, and the quantity of filver afterwards determined by the method above mentioned (*c*).

(*c*) Artificial falited filver may, without any confiderable lofs of the metal, be reduced in the following manner :—let the mafs be mixed with an equal bulk of alkaline falt in a glafs mortar, and by means of a few drops of water be formed into a globule; let this globule be put into a crucible, the bottom of which has previoufly been ftrewed with fal fodæ, compreffed, and well covered with the fame alkali; an heat fufficient for fufion being then applied, the whole of the metal will be recovered if the falited filver has been accurately collected.

§ VI. *Ores*

§ VI. *Ores of Mercury.*

Mercury is afforded by nature, either native or mineralized by ſulphur or acids.

(A) When native it is eaſily diſtinguiſhable by its fluidity, and is ſeldom mixed with any other metals but gold, ſilver, or biſmuth, which frequently exiſt native, and are very eaſily ſoluble by this liquid metal; if any of theſe be preſent, the firſt remains at the bottom, when the mercury is diſſolved in nitrous acid; the third is indeed taken up by the menſtruum, but precipitated by water; and the ſecond is diſcovered by ſea-ſalt, which alſo precipitates at the ſame time a ſalited mercury, which is eaſily ſeparable by its greater ſolubility.

(B) In cinnabar the union between the ſulphur and the metal ſeems to be more complete than in other mineralizations, as it cannot be decompoſed either by vitriolic, nitrous, or marine acid. I have even attempted to diſunite them by a ſolution of cauſtic fixed alkali in water, and by boiling for many hours, but in vain. However, there are two ways of effecting a perfect decompoſition; one by gently boiling for an hour the cinnabar with eight times its weight of an aqua regia, one fourth of which conſiſts of marine acid; the other by boiling it in marine acid, with the addition of $\frac{1}{10}$ the cinnabar's weight of black calx of manganeſe.

manganefe. In both cafes the menftruum is the fame, namely, a dephlogifticated marine acid; but in the firft cafe the acid is dephlogifticated by the nitrous acid, in the latter by the calx of manganefe; the former is however the beft, as no heterogeneous matter is fuperadded.

By whatever method the metallic part of the cinnabar is diffolved, the feparated fulphur may be collected by a filter, and the mercury precipitated by zinc: copper precipitates falited mercury in a more imperfect manner.

If the cinnabarine ore under examination be very much entangled in the matrix, it muft be freed from it as much as mechanically can be done by lotion; then the foluble parts of the matrix taken away by nitrous, marine, or vitriolic acid, occafionally; and finally, the metal itfelf feparated by aqua regia.

(c) Mercury has alfo lately been difcovered mineralized (*d*) by the vitriolic and marine acids. The former may be feparated by the help of marine acid, by trituration or digeftion, and the metal precipitated by nitrated terra ponderofa; but the weight of the new earthy falt a, being given, we can eafily learn the quantity of metal (as before obferved § v.): yet as nitrated mercury is not totally precipitated by

(*d*) Mr. Woulfe was the firft who difcovered that thefe two acids act as mineralizing fubftances with refpect to mercury.

 vitriolated

vitriolated mineral alkali, we muſt not here depend upon the weight of the precipitate. By another proceſs, therefore, we obtained from 100 of vitriol of mercury 33,899 of pure metal, and from an equal weight of corroſive ſublimate 75,5; from whence the data of a calculation are eaſily deduced: for, let the quantity of vitriolic acid = 0,15 a; the vitriol of mercury containing this = 0,44 a; and the ſalited mercury = 100 — 0,44 a. In the former ſalt the mercury conſtitutes 0,29 a, and in the latter 72,5 — 32 a; ſo that the whole metallic content in 100 = 72,5 — 03 a. But as the ſcarcity of this ore has not permitted us to examine it ſufficiently, we are ſtill ignorant whether the ſalited part is to be compared with corroſive ſublimate or mercurius dulcis; if the latter, the calculation comes out different; for in the latter of theſe two ſalts the metal forms above 0,91, and the whole content is exhibited by the following formula; 91,18 + 0,29 a — 0,40 a = 91,18 — 0,11 a.

§ VII. *Ores of Lead.*

Whether nature ever produces lead native is ſtill in diſpute. The moſt common ore contains it mineralized by ſulphur, generally mixed with ſilver, ſometimes alſo with iron and antimony together. That which is commonly called calciform lead, contains the

the metal united with the aerial acid, or the acid of phoſphorus.

(A) Lead, if ever found native, may be eaſily examined as to purity, by means of nitrous acid, which diſcovers copper both by its blue colour and its precipitation by iron; and ſilver is betrayed by the addition of copper.

(B) When united with ſulphur, and freed from any matrix, let it be reduced to a fine powder; let this be boiled in nitrous or marine acid until the ſulphur is obtained pure, collected on a filter, waſhed, and dried. Its purity is aſcertained by cauſtic fixed alkali.

Let the ſolution be precipitated by aerated mineral alkali, when the lead is either alone or mixed with ſilver; in the former caſe, ſuppoſing the weight of the precipitate = a, the weight of the reguline lead will be $\frac{100\,a}{132}$; if the latter, let the ſilver be extracted by volatile alkali, and the reſiduum multiplied into the conſtant coefficient $\frac{100\,a}{132}$ will expreſs the lead. The aerated ſilver is known by the diminution of weight; if this be = b, then the ſilver in a metallic form = $\frac{100\,b}{129}$.

The ſolution made in marine acid during the operation depoſits a large quantity of ſalited lead, which muſt be diſſolved in water before the precipitation.

If antimony be preſent, this is ſo much dephlogiſticated by concentrated nitrous acid, that it is calcined and falls to the bottom: the given weight of this, multiplied by the conſtant coefficient $\frac{100}{138}$, indicates the regulus in the muriatic ſolution; this ſpontaneouſly falls, upon dropping in water, which takes up the ſalited lead.

Iron, which yet is but ſeldom found in galena, may thus be diſcovered:—let the muriatic ſolution be firſt ſo far ſaturated with fixed alkali that the acid may predominate only a little, and yet all precipitation be ſolicitouſly avoided. This being done, the lead will be precipitated by a poliſhed plate of iron, added during boiling; as alſo will the ſilver, which is almoſt always preſent: finally, let the iron be precipitated by aerated or phlogiſticated alkali (§ IX.); and its weight corrected by the part of the metallic plate which is diſſolved during the precipitation.

If the ore contains any matrix, this is either ſoluble, and may at firſt be ſeparated by vinegar, or elſe is inſoluble in the common acids, and is found collected at the bottom.

(C) Lead, mineralized by aerial acid, and deprived of all heterogeneous ſoluble mixture, may be diſſolved in nitrous acid, and precipitated by aerated mineral alkali; which being done, the quantity of lead is known by the weight of the precipitate, as before (B).

But if the matrix containing it be ſoluble, let the marine acid be employed, and

and the metal precipitated by iron, as above defcribed.

(D) Lead, mineralized by acid of phofphorus, is eafily diftinguifhed. 100 of this, in powder, is diffolved in nitrous acid by means of heat, except a few martial particles, which generally remain at the bottom. The diffolved lead, upon the addition of vitriolic acid, immediately forms a fnowy white vitriol, which wafhed, collected, and dried, may be fuppofed to weigh a, in which cafe the correfponding lead is = $\frac{100\,a}{143}$. The liquor remaining after the precipitation yields, by evaporation to drynefs, a phofphoric acid.

The colour, both of this and the former ore, is owing to iron; generally they are green, fometimes yellow, but rarely red; they occur white, and fometimes pellucid; and all affect a cryftalline, efpecially a prifmatic form.

§ VIII. *Ores of Copper.*

Copper, befides its metallic form, affumes a variety of fhapes: it is generally united with fulphur, and very feldom without iron; but it alfo fometimes occurs mineralized by aerial, vitriolic, and even by marine acid.

(A) Native copper readily diffolves in nitrous acid; if gold be prefent, it falls, untouched, to the bottom, in form of a black powder; if ſilver, it is ſoon precipitated by copper; if iron, by boiling the ſolution for ſome time, and inſpiſſating to dryneſs, it is gradually calcined, and ſeparates.

(B) When mineralized by ſulphur, let it be powdered and gently boiled to dryneſs in five times its weight of concentrated vitriolic acid; let the reſiduum be well waſhed with water, until all the metallic part has entered the menſtruum.

The ſolution requires at leaſt a portion of water equal to four times the vitriol which is to be diſſolved, and therefore the quantity ſhould be adapted in ſome degree to the goodneſs of the ore: that which contains 0,05 of copper requires about 0,8 of water, and ſo on. Let a poliſhed iron plate, about twice the weight of the copper, be immerſed in the ſolution properly diluted; let boiling be continued until no further precipitate is occaſioned. If the quantity of water be too ſmall, the precipitated metal adheres very pertinaciouſly to the iron plate, which, by a proper quantity, is always completely freed. Let the precitated copper, well waſhed, be ſpeedily dried; but yet with ſuch a degree of heat as to make the ſurface of the metal of different colours, which inſtantly and ſenſibly increaſes the weight.

If the precipitated copper be found mixed with iron, which is ſometimes the caſe,

 eſpecially

eſpecially in the examination of a poor ore, this muſt be again diſſolved, to obtain a richer ſolution; which depoſits pure copper, if the operation be conducted as above deſcribed. The ſame circumſtance takes place in the precipitation of ſilver by copper; a rich ſolution yields the metal pure, but a poor one yields it allayed with copper.

If the copper to be precipitated contains other metals, theſe may eaſily be ſeparated by ſolution in the nitrous acid. Gold remains at the bottom, undiſſolved, in the form of a black powder; and ſilver precipitates upon a copper plate.

During this proceſs, the whole, or a great part of the ſulphur, flies off by the intenſe heat neceſſary for evaporating the vitriolic acid to dryneſs; yet its quantity may in ſome degree be judged from the ſum of the weights of the other ingredients, compared with the weight of the whole; beſides, if thought neceſſary, a ſolution in aqua regia may be made for the purpoſe of collecting the ſulphur.

(c) Copper, mineralized by aerial acid, is of an elegant green colour, and is commonly called malachites; to this alſo belongs the green ſilken ore of copper, which is of the ſame nature. Theſe ores, when pure, are totally ſoluble in acids, and may be precipitated either by iron or aerated alkali. In the latter caſe, ſuppoſing the weight of the precipitate to be = a, the metallic copper contained will be $\frac{100\ a}{194}$ (*i*).

If calcareous earth be mixed, which ſometimes happens, this may be thrown down by aerated alkali, after the precipitation of the metal by phlogiſticated alkali.

Calciform blue copper conſiſts alſo of copper mineralized by aerial acid. Its principles are diſcovered in the ſame way.

Calciform red copper, or of a browniſh red, is called by Mr. Cronſtedt the glaſſy ore of copper. This alſo is totally, or for the moſt part, diſſolved, and that with an efferveſcence, though ſomewhat weaker than the other; ſo that it is doubtful whether any calciform ore of copper is entirely deſtitute of aerial acid. I have not ſeen the red pellucid ore lately diſcovered and deſcribed by Mr. Sage.

I have examined in many different ways the red quartz, which is ſuppoſed by Mr. Cronſtedt (*k*) to contain ſuch a calx. The

(*i*) The illuſtrious Fontana was the firſt who determined the true nature of the malachites. He found that it contains $\frac{2}{3}$ of calcined copper, $\frac{1}{4}$ of aerial acid, and about $\frac{1}{18}$ of water. The ſame principles he diſcovered in the green ſilken ore, their proportions only being ſomewhat varied. This obtains alſo with reſpect to the blue ore; but in this the aerial acid forms a larger part of the whole, amounting nearly to $\frac{1}{3}$ or $\frac{1}{2}$; on the other hand, in the ſpecimens which have been examined, the proportion of the water is diminiſhed by $\frac{1}{72}$ to $\frac{1}{57}$.

(*k*) Mineralog. § 196. b. 2.

volatile alkali did not extract any copper, nor did the vitriolic acid, though abſtracted to dryneſs. As the ſiliceous matrixes hardly admit the menſtrua, I added a portion of the mineral fluor to the vitriolic acid; for the fluor acid, when expelled, attacks the quartoſe particles, ſo as to ſet at liberty even the laſt portions of copper; but although this experiment always ſucceeds when copper is preſent, yet in the inſtance of this ore not the ſmalleſt ſign of that metal could be diſcovered; and therefore it is not without reaſon that we doubt of its preſence.

(D) Copper, mineralized by vitriolic acid, is no other than the common blue vitriol, which ſometimes occurs native. The copper it contains is eaſily precipitated by iron in the manner above deſcribed.

(E) In the collection of the Academy of Upſal there occurs a ſpecimen of a dilute greeniſh red, friable, and of ſmall ſpecific gravity, which diſſolves with efferveſcence in nitrous acid, imparting a green colour to the menſtruum. Upon the addition of iron the copper is precipitated; and upon dropping in a ſolution of ſilver, a white coagulum is ſeparated, being a genuine ſalited ſilver; ſo that no doubt can be entertained of the preſence of marine acid, an opinion which is alſo eſtabliſhed by the via ſicca in many ways, which I here paſs over.

We find veſtiges of the ſame acid in the beautiful green ore of Saxony, which is cubic or ſquamous, and has been referred to the ſpecies of mica or talc. I have lately, by favour of Mr. Werner, had an opportunity of examining a ſpecimen interſperſed as it were with this ſubſtance. It diſſolves totally in nitrous acid, and acquires a green colour: the copper is diſcovered by many precipitants, as by iron, by volatile and phlogiſticated alkali; but the marine acid is diſcovered with far more difficulty; yet upon dropping in a ſolution of ſilver, a true luna cornea falls, but in ſmall quantity; there appears a portion of green ſcales, which did not weigh one grain; the ſmallneſs of the quantity prevented me from making any further experiment; but thoſe already made put it beyond doubt that this deſerves a place among the ores of copper; it contains alſo a little clay, but the quantity remains to be determined by experiment on larger quantities.

§ IX. *Ores of Iron.*

Traces of this moſt common of all metals are found almoſt every where in the mineral kingdom; yet the ores which contain it in conſiderable quantity preſent it either mineralized by ſulphur, or more or leſs calcined: it is rarely found united with vitriolic

vitriolic acid; and very ſeldom in a complete metallic form.

(A) Mineralogiſts are not yet agreed whether iron be found native. Concerning that of Siberia, a diſpute is ſtill carrying on; and indeed it cannot be denied, but that the cavities in the iron maſs ſhew it to have been fuſed, and as it were inflated by ſpumeſcence; yet many circumſtances ſeem to indicate, that if this operation ever took place, it was performed without the aſſiſtance of art. The ſtoney matter which fills all the cavities is of a very different nature from the ſcoriæ produced in our furnaces. To paſs over its ſituation, and other circumſtances, the iron itſelf, when cold, or moderately warm, is found to be very tenacious and malleable; but when made red hot becomes brittle, but exhibits altogether the ſame phænomena, when examined by the via ſicca, as forged iron; with marine acid it diffuſes an hepatic odour, which evidently ſhews the preſence of ſulphur, phlogiſton, and the matter of heat, as without theſe no ſuch ſmell ever ariſes. It is probable that the matter of heat is taken from the fire by the metals in fuſion; yet we cannot therefore certainly conclude, that every thing which contains the matter of heat has been expoſed to fire: and ſuppoſing that the Siberian iron has undegone fuſion, it cannot from thence be inferred, that this has been occaſioned by art. But this

this very rare mineral deſerves to be ſeparately and particularly examined.

Ores of iron are frequently found in Sweden ſo perfect as to be obedient to the magnet, nay, ſometimes are themſelves magnetic; but theſe, both with reſpect to menſtrua and other properties, differ from iron eliquated by fire. Such iron as may properly be called native may yet be brittle; for that which is extracted artificially, and is malleable, eaſily contracts brittleneſs, but muſt with menſtrua preſerve the ſame habits as the forged.

(B) The attractive and magnetic ores, though they do not contain much ſulphur, yet are ſeldom entirely without it; but none of it could be extracted by menſtrua.

Such as are ſaturated with ſulphur, are called ſulphureous pyrites, as nothing but ſulphur is extracted from theſe; for although they ſometimes contain enough of the metal to pay the expence of eliquation, yet the metal extracted by its brittleneſs is rendered intractable in the fire; and, expoſed to the open air, eaſily falls into a ruſt.

(C) Iron, mineralized by vitriolic acid, is produced daily by the ſpontaneous decompoſition of pyrites, which is again gradually ſo dephlogiſticated as at length to loſe all connection with the acid. Theſe vitriolic reliquiæ, waſhed away and depoſited in lower ſituations, perhaps generate the ores of lakes and marſhes.

(D) The

(D) The hæmatites yield a calx of iron under various forms, of an iron colour, a red, a black, or a yellow. Other ores alſo contain it, but of a lax and powdery texture, generally mixed with other earths.

Whether any of theſe ores contain iron naturally mineralized by aerial acid in the boſom of the earth, is yet unknown. Artificially, this ſubtile acid is greedily taken up; but all the natural calxes of iron hitherto examined ſhew no ſigns of it, except the white ores of iron; but as theſe contain aerated mangeneſe and calcareous earth, it is doubtful whether the martial particles contribute to furniſh any of the aerial acid extricable from theſe ores.

(E) All the ores of iron, reduced to a very ſubtile powder, and repeatedly boiled in marine acid, yield up the metal. If the pyrites are more ſlowly diſſolved, the addition of a ſmall quantity of nitrous acid accelerates the operation.

The iron being extracted, the matrix, if inſoluble, remains. Now, in order to obtain the metal alone, let it be all ſeparated by phlogiſticated alkali. Suppoſe the precipitate, when waſhed and dried, = a, then the correſponding quantity of metallic iron will be $\frac{a}{6}$; but this formula muſt be corrected according to the quantity of the precipitant, as before obſerved (§ 11.).

That which is of itſelf ſoluble by means of of vitriolic acid, requires nothing but water to precipitate by phlogiſticated alkali.

Manganeſe is frequently united with iron, and is diſcovered without difficulty by immerſing the blue ſediment (carefully weighed) in water ſharpened by nitrous acid, by which the part ariſing from the manganeſe is diſſolved, as we ſhall ſee hereafter (§ XVII.). Other methods of effecting this are deſcribed elſewhere (*l*).

Beſides this metal, there are others which enter the ores of iron in ſtill larger quantities, which for the moſt part render the ores uſeleſs, by imparting noxious qualities to the eliquated iron.—We ſhall ſpeak of zinc, &c. and of the manner in which they are to be ſeparated, in their proper places.

§ X. *Ores of Tin.*

Many teſtimonies concur in aſſerting that tin is found native in England; but I have never met with any ſpecimen of it.

But the ores of tin almoſt always preſerve the ſame cryſtalline nature, although the grains are often found ſo ſubtilely diſperſed in different matrixes as entirely to elude the ſight. I have lately obtained a peculiar variety found in England, which,

(*l*) Eſſay on the White Ores of Iron, § VIII.

conſiſting

conſiſting of contiguous ſphærical ſtrata, and radii proceeding from a center, very much reſembles the brown hæmatites. In all theſe tin is preſent, ſimply calciform, and involved in ſiliceous particles; and, ſo far as is yet known, never mineralized, either by marine or aerial acid, or by ſulphur. The abſence of the latter is the more extraordinary, as this mineralizing ſubſtance is produced by nature in great quantities, and is artificially united to tin with great eaſe.

(A) The examination of tin by the humid method is attended with no difficulty; for the addition of nitrous acid quickly deprives it ſo far of its phlogiſton, as to reduce it all to a white calx; the iron and copper, if any be preſent, remaining in the liquor. 100 parts of tin, corroded by nitrous acid, waſhed and dried, yield 140 of white calx: arſenic may be ſeparated by waſhing the calx with large quantities of warm water; for but little enters the acid menſtruum. The other metals are but rarely united with truly native tin.

(B) The pure ore is commonly called, according to the magnitude of its cryſtals, *zinngrauſſen*, or *zwitter*. The examination of theſe forms is the great difficulty of the humid method, as they are not acted upon effectually either by vitriolic, nitrous, or marine acid, or by aqua regia.

The reaſon of this pertinacity is, that the calx, being well dephlogiſticated, is either not

not taken up at all, or very ſparingly, and is beſides involved in ſtoney particles, which elude the action of the acids. The method by which this proceſs ſeems to be moſt nearly effected, is as follows :—

To a very ſubtile powder of this ore, obtained not only by levigation but elutriation, let there be added a quantity of concentrated vitriolic acid, and let this be expoſed to a ſtrong digeſting heat for ſeveral hours; then let there be poured on a ſmall portion of concentrated marine acid, and upon agitating it a vehement efferveſcence immediately begins with conſiderable heat, ariſing from the marine acid, which is partly deprived of its water by the vitriolic, and generates a marine acid air: by this method the forces of the two acids are conjoined. After the ſpace of about an hour, let water be added, and upon ſubſiding the clear liquor decanted. This operation is to be repeated with the reſiduum, until the acids can diſſolve no more.

What remains finally undiſſolved, is nothing more than the ſtoney matrix.

Let the ſolution, precipitated by means of aerated alkali = a, and the quantity of regulus ſought will be $\frac{100}{131}$ a.

The ſubtile atoms of the cryſtalline ore, intimately mixed with any matrix, may, after due pulverization, be ſeparated by waſhing from a given portion, as the cryſtals are nearly of ſix times greater ſpecific gravity

gravity than water; ſo that they not only exceed the earthy particles, but the ores of other metals, and approach even to the lighter metals themſelves. The cryſtalline particles, after being ſeparated, are expoſed to the trial above-deſcribed, the larger diſtinct cryſtals can ſeldom be employed; the moſt common ore contains particles of them very much diſperſed.

The adventitious metals uſually found in ores of tin, are copper and iron.

§ XI. *Ores of Biſmuth.*

Biſmuth, which is the moſt ponderous of the ſemi-metals, occurs partly native, partly mineralized by ſulphur, and ſometimes perhaps even by the aerial acid. Some deny that this metal is found naturally united with ſulphur, but without foundation; for although ſuch has not yet been found in Germany, it is undoubtedly obtained in many mountains of Sweden, eſpecially at Ridderhyttan in Weſtmania. Calciform biſmuth is of a white colour, but it rarely occurs; ſo that it cannot yet be certainly determined whether it be mineralized by aerial acid or not.

(A) Native biſmuth is eaſily taken up by nitrous acid, and may then be precipitated by water; which done, if any other metals are mixed with it, they remain in the liquor, and

and may be ſeparated as above-deſcribed in various places.

(B) When mineralized by ſulphur, it is decompoſed by ſlight boiling in the ſame menſtruum; ſo that the ſulphur may be at laſt obtained, which when waſhed and collected, is to be examined as to its purity and quantity.

The ſolution of the metallic part, precipitated by water, yields a white calx; let its weight = a, and that of the correſponding metal will be $\frac{100\,a}{113}$.

In theſe mineralizations iron is ſometimes found, which, after the ſeparation of the biſmuth, is eaſily diſcoverable.

(C) Calciform biſmuth, whether alone, or mineralized by aerial acid, alſo enters the nitrous acid, and may be precipitated by water, upon which the heterogeneous matters remain in the liquor. The preſence of cobalt is diſcoverable immediately, by its communicating a red colour.

§ XII. *Ores of Nickel.*

Nickel is found, but very ſparingly, mixed with other matters, yet it appears under a variety of forms; ſometimes native, or united with a little ſulphur, yet at the ſame time intimately united with iron, cobalt, and arſenic; ſo that theſe adventitious metals cannot be ſeparated without much difficulty,

difficulty, and the iron hitherto but imperfectly; but it occurs mineralized by the vitriolic, and poſſibly by the aerial acid.

(A) Native nickel is taken up by nitrous acid, and when precipitated by aerated alkali, yields a calx which almoſt always contains iron, arſenic, and cobalt, in the ſame proportions in which they generally accompany the regulus eliquated in the uſual way: if ſilver and biſmuth happen to be alſo preſent, which yet is very rarely the caſe, the former is to be precipitated by muria before the alkali is employed.

(B) If ſulphur be preſent, it may be ſeparated and collected during ſolution.

(C) Nickel, mineralized by vitriolic acid, is ſcarcely ever without iron; a great part of the martial inquinament is ſeparated by long and violent boiling in water. Aerated alkali throws down a greeniſh white precipitate: let the weight of this = a, and the common reguline nickel is $= \frac{100\,a}{135}$.

(D) The ſame metal, mineralized by aerial acid, is diſſolved by the nitrous acid, and precipitated by means of aerated alkali.

A more compleat account of the examination of this metal, may be found in a preceding treatiſe.

§ XIII. *Ores of Arſenic.*

Arſenic is produced by nature, both reguline, mineralized by ſulphur, and calciform.

(A) If the purity of native arſenic is to be examined, let it be diſſolved in four times its weight of aqua regia, and the ſolution ſlowly evaporated, without any ſeparation of the metal; after this, let the arſenic be precipitated by water, and collected upon a filter; the clear liquor which paſſes through will contain the heterogeneous metals: if any ſilver be preſent, it ſeizes the marine acid, and falls to the bottom.

Iron is ſcarce ever entirely abſent, and is frequently in ſuch quantity that the maſs appears poliſhed, moſt commonly cryſtalline, and is vulgarly known by the name of miſſpickel, which is with juſtice conſidered as belonging to native arſenic, as it neither contains any ſulphur, nor any mineralizing acid. It muſt indeed be confeſſed, that arſenic itſelf is nothing more than a peculiar acid coagulated by phlogiſton, in a manner ſimilar to ſulphur; but the ſame thing is perhaps true of all the metals; and beſides, the acid of arſenic, when loaded with phlogiſton, puts off its acid nature, and therefore in that caſe cannot be looked upon as a mineralizing ſubſtance; but if at any time

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it ſhall be found in the boſom of the earth, united in the manner of an acid menſtruum to any metal, it then beyond doubt is to be conſidered as a mineralizing ſubſtance.

(B) Let arſenic, mineralized by ſulphur, be diſſolved in marine acid, with the addition of the nitrous occaſionally, in greater or leſſer quantity, ſo that the ſulphur may be ſeparated free from all the metallic matter. The ſulphur collected, waſhed, and weighed, indicates the quantity of the arſenical part; this however ought to be precipitated ſeparately by water, and weighed, a ſtep which is neceſſary wherever great accuracy is required. Salited arſenic may alſo be precipitated in its metallic form, by zinc, the ſolution being previouſly weakened by ſpirit of wine.

When ſulphur alone is united to the arſenic, by its different proportions it produces different colours, from a dilute yellow to an intenſe red; but if a conſiderable portion of iron alſo enters the compoſition, a white colour is generated, and a very different ſpecies of pyrites formed, which is called the arſenical pyrites: the metallic principles of this, diſſolved in marine acid, or aqua regia, may be ſeparated in the manner above deſcribed.

(c) Calciform arſenic, which nature ſeldom produces, is diſſolved and examined by means of marine acid.

In general, concerning arſenical ores, we muſt guard againſt uſing too much nitrous acid, as by that the whole of the phlogiſton is readily taken away, and the acid diſengaged: the ſmalleſt quantity therefore which is ſufficient for ſolution ſhould be employed, otherwiſe water will occaſion no precipitation; and, notwithſtanding all our caution, it is ſcarce poſſible to prevent the diſengagement of a portion of the arſenical acid, eſpecially if the boiling be long continued; this may be recovered by evaporating to dryneſs, yet rarely alone, but occaſionally, and according to the laws of attraction, united either with the alkaline earths, or the metals which are preſent (*m*). Some of the arſenic eaſily flies off.

§ XIV. *Ores of Cobalt.*

Reguline cobalt often occurs totally deſtitute both of ſulphur and acids, that is,

(*m*) Regulus of arſenic may be very commodiouſly obtained in the following way, by the via ſicca:—white arſenic, with three times its weight of black flux, is put into a crucible, which is covered by another, and luted ſo cloſely that the acceſs of external air is altogether prevented. This being done, the lower crucible is gradually expoſed to a red heat, and in the mean time the upper crucible is protected from the effects of the fire by means of a copper plate; by this method, the inner ſurface of the upper crucible is covered with a poliſhed, cryſtallized, reguline cruſt, which may in general be ſeparated whole by a gentle concuſſion.

native, and only mixed with other metals; it is alſo found united with ſulphur, and mineralized by the acids of vitriol and arſenic. Nature moreover exhibits a black calx of cobalt: it is not yet certainly known whether it is ever loaded with the aerial acid.

(A) When native, it almoſt always contains iron and arſenic, and often nickel; and hence no doubt it is, that ſome authors aſſert that vitriolated cobalt, and the other ſalts containing this metal, are of a green colour; whereas they really are of an obſcure red, unleſs the nickel be in large quantity. In order to ſeparate theſe metals, let the mixture, diſſolved in aqua regia, evaporate to dryneſs, and let the cobalt be extracted by vinegar; ſuppoſe this, precipitated by aerated alkali, be in weight = a, then the correſponding quantity of regulus= $\frac{100\,a}{160}$. We have already treated of the nickel and the iron (§ XII.); if the arſenic be ſuperabundant in the evaporated ſolution, it may perhaps be precipitated by water.

(B) Cobalt united with ſulphur may be treated in the ſame way, as it differs from the native cobalt only in containing a ſmall quantity of ſulphur, which is to be ſeparated and collected.

(C) The celebrated Mr. Brandt has diſcovered Cobalt joined to vitriolic acid, with a large quantity of iron, and without any arſenic. This I have examined in the humid way, by ſolution in aqua regia. The yellow ſolution, on account of abundant iron, was ſcarce red, but by boiling aſſumed an obſcure green, and upon cooling recovered its former colour; a property which diſtinguiſhes cobalt. No ſulphur could be collected; but a few drops of ſalited terra ponderoſa, diſſolved in water, immediately diſcovered the vitriolic acid. Scarce any arſenic appeared.

If in this inſtance the vitriolic acid be preſent in a dephlogiſticated ſtate, as appears to be the caſe (unleſs we rather chuſe to ſuppoſe that a very few particles of ſulphur have been dephlogiſticated during the ſolution) yet this acid is not preſent in ſuch quantity as to give birth to a vitriolated cobalt; for the maſs is of a metallic nature, and therefore the acid is to be conſidered only as an inquinament.

The trichites of the Greeks, which is found in the mines of Herngrund and Idria, adhering to an argillaceous ſtone, is found to contain ſomewhat of a real cobalt, beſides the clay and vitriolic acid; this can be precipitated only by a phlogiſticated alkali.

(D) Cobalt frequently exhibits beautiful red efflorеſcences, of a colour ſometimes more dilute, ſometimes more ſaturated; it appears now like a looſe powder, now concrete; nay at times it forms moſt beautiful cryſtals, radiating from the ſame center in the

the manner of a ſtar. Theſe ſubſtances always ſhew ſome veſtiges of arſenic; but neither reguline nor white arſenic are capable of imparting the red colour to cobalt; this can only be effected by acids. Since therefore the colour indicates the preſence of an acid, it is reaſonable to conclude it to be the arſenical acid. The white arſenic, which is almoſt always adhering to the ores of cobalt, may perhaps be ſometimes ſo much dephlogiſticated by time, that the acid, being extricated, is in a condition to act upon the contiguous particles of cobalt.

In order either to eſtabliſh or to overthrow this ſuſpicion, I thought it proper to conſult experiments. I found an exact correſpondence to ſubſiſt between cobalt, artificially ſaturated with acid of arſenic, and the natural red cryſtals of cobalt, except that the latter ſometimes contained white arſenic. The arſenicated cobalt is not taken up by water, unleſs the acid be ſuperabundant; and this it is, perhaps, which prevents the ſeparation of arſenicated lime, upon the addition of ſal ited lime to the ſolution; however, the event of the experiment is the ſame, whether the arſenicated cobalt employed be natural or artificial;—on evaporating to dryneſs an arſenicated lime appears.

On account of the ſcarcity of this ſubſtance, I inſtituted another experiment in ſmall:—I extracted the pure acid of arſenic, firſt ſeparating it by vitriolic acid, and then

 abſorbing

abſorbing it by highly-rectified ſpirit of wine; for this laſt does not take up the vitriolated cobalt, but only the diſengaged acid.

Natural arſenicated cobalt is ſcarcely ſoluble in water, unleſs the water be ſharpened by an acid, and when thus diſſolved it ſhould be precipitated by aerated alkali, to diſcover the quantity of reguline cobalt. Cobalt, artificially arſenicated and ſufficiently dried, ſhews the ſame properties as the natural.

(E) I have ſometimes examined earths more or leſs compact, green or blue, which appear to contain a little cobalt; but in theſe ſpecimens copper abounded, more eſpecially in the blue, which alſo effervеſce violently in acids. Let the copper be firſt precipitated from the ſolution by iron, the liquor evaporated to dryneſs, and the cobalt diſſolved by vinegar; if any of the iron adheres to the vinegar it ſeparates on boiling.

(F) The black calx of cobalt is generally found concreted into an hard maſs, known by the name of glaſſy ore of cobalt; this, when pulverized, is taken up by aqua regia or marine acid, and may be examined like the former. I have not certainly diſcovered in theſe the aerial acid.

§ XV. *Ores of Zinc.*

Many ſtill doubt whether zinc be ever found native; it is ſeen mineralized by ſul-

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phur in the pſeudo galena; by vitriolic acid, in native white vitriol; and by aerial acid, in lapis calaminaris, and in the other ores which are called glaſſy.

(A) If at any time native reguline zinc, without any artificial aſſiſtance, be found, its purity may be eaſily examined, as it is quickly diſſolved in all the common mineral acids, and whatever heterogeneous metal is preſent may be precipitated by zinc. The factitious white vitriol rarely contains any other metal, except lead.

(B) The pſeudo galena, which contains zinc mineralized by ſulphur, together with iron, muſt be carefully treated with nitrous acid, in order to extract the metallic part without injury to the ſulphur: if no other metal than iron be preſent, let it be precipitated by zinc; but if more, the iron muſt be calcined by repeatedly abſtracting nitrous acid to dryneſs, and the new ſolution, made by vinegar or any other menſtruum, examined.

Hepatic air is generated by the vitriolic, and ſtill more copiouſly by the marine acid; but as this elaſtic fluid conſumes a part of the ſulphur, I have rather directed the employment of nitrous acid with caution in the ſolution of pſeudo galena.

(C) Let the zinc, united with vitriolic acid, be diſſolved in water, and precipitated by an aerated alkali; let the weight of aerated

aerated be a, and that of the reguline metal zinc is $\frac{100a}{193}$.

If, as is generally the caſe, iron be preſent, this ſhould be precipitated by a known weight of zinc.

(D) Zinc, mineralized by aerial acid, and diſſolved in acids, ſhould be precipitated either by aerated or phlogiſticated alkali; in the latter caſe, or in order to determine the metallic part, the weight of the ſediment muſt be divided by 5.

In the Treatiſe on Zinc we have deſcribed at large how the matrix and other heterogeneous matters are to be ſeparated on different occaſions.

A zinc, mineralized by ſpar, has lately been diſcovered (*n*); and I hope, by favour of the illuſtrious diſcoverer, that it will be ſoon examined by the humid way, as the mineralizing ſubſtance (*o*) is hitherto unknown.

§ XVI. *Ores of Antimony.*

Stibium, commonly called *antimony*, has as yet been met with only under two diffe-

(*n*) By Mr. Von Born.

(*o*) It is always extremely difficult to extract zinc from its ores in the via ſicca. The ore roaſted with charcoal-duſt in the way deſcribed in note (*m*), it is true, yields ſeveral particles of zinc in the upper crucible, eſpecially if that crucible be perforated by an hole, and covered above by another, well luted on; but hitherto it has been found impracticable to ſublime more than one half of the contents of the lower crucible.

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rent forms, namely native, or mineralized by ſulphur.

(A) Mr. Suab, in 1748, firſt diſcovered native antimony in a calcareous matrix at Sahlberget, nor do I know that it has been found any where elſe; however, in the collection of the Academy, there is a ſmall piece found ſomewhere out of Sweden, but where is uncertain; this is in a quartoſe matrix: ſo that it appears native antimony is found in other places, though rarely, and though little known in this country.

The purity of the metal is moſt conveniently examined by reducing it to a calx with ſtrong nitrous acid; for this being done, if it be entirely pure, there will remain diſſolved in the menſtruum only a ſmall part, which ſeparates upon the addition of water.

(B) The metallic part of antimony, mineralized by ſulphur, is taken up by aqua regia, and the ſulphur remains pure. The ſolution, mixed with ſtrong nitrous acid, on boiling depoſits a calcined antimony, which being ſeparated, the remaining liquor may be examined by phlogiſticated alkali, or any other means.

Sulphurated antimony, by a certain quantity of arſenic, grows red, frequently exhibiting beautiful faſciculi of filaments radiating from a center. If arſenic be preſent it is thus diſcovered :—let the powder be gently boiled in aqua regia until the ſulphur is obtained

obtained pure; the clear ſolution contains the antimony and arſenic, which are ſeparated in the following manner:—let concentrated nitrous acid be poured on, and the antimony reduced to a white calx by boiling; let this be collected on a filter, and the liquor that paſſes by evaporation yields the arſenic, generally ſpoiled of phlogiſton, that is, the arſenical acid.

Beſides, as the cauſtic alkali takes up both ſulphur and antimony, this, aided by heat, may be advantageouſly employed, eſpecially for the ſeparation of ſilver or other metals which do not yield to this menſtruum; an hepar is indeed generated, but in this inſtance it diſſolves little or nothing.

§ XVII. *Ores of Manganeſe.*

The newly-diſcovered ſemi-metal, manganeſe, accompanies moſt ores of iron, as has been before obſerved (§ III. C). It has however ores of its own, in which it predominates, though they are ſeldom to be found; it has no where yet been obſerved native, nor mineralized by ſulphur, unleſs when joined with other metals in larger quantities; it commonly occurs calciform, but under various forms; generally alone and black, ſometimes mineralized by aerial acid.

(A) Calciform manganeſe alone generally poſſeſſes a metallic ſplendor, is partly of

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an earthy colour, black or red: the colours are no doubt owing to unequal portions of phlogiſton.

Let theſe ores, reduced to a ſubtile powder, be immerſed in any, but particularly a mineral acid, together with a ſmall piece of ſugar. It is known that the calx of this metal eludes the force of acids, unleſs ſomewhat be added to ſupply the neceſſary quantity of phlogiſton. Let freſh acid be repeatedly poured on with ſugar, until no more is extracted by a digeſting heat; let the ſolution collected be precipitated by aerated alkali; let the weight of the ſediment be a, and the correſponding regulus will $= \frac{100\,a}{180}$.

What remains undiſſolved at the bottom either belongs to the matrix, or contains heterogeneous mixtures.

(B) Aerated mangancſe is rarely found pure but in the gold mine at Nagyay: when it forms the matrix, it is had ſcarcely mixed with iron; at leaſt, in a ſolution made with nitrous acid, the phlogiſticated alkali does not diſcover it. In general the iron is in larger quantity, as in the white ores of iron; but theſe ores are to be treated as before deſcribed.

In order to ſeparate the iron when it abounds, or at leaſt the greateſt part of it, let nitrous acid be repeatedly abſtracted to ignition from the ore; after which the manganeſe pure, or at leaſt not much contaminat-

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ed by iron, may be ſeparated by ſtrong concentrated vinegar, or diluted nitrous acid.

Manganeſe, precipitated from ſuperabundant nitrous acid, by phlogiſticated alkali, diſſolves totally in diſtilled water; a property which affords a method of ſeparating it from iron.

We cannot poſitively aſſert whether manganeſe, joined to marine acid, is ever found in the boſom of the earth; although it ſeems probable, on the ſuppoſition that natural waters are ſometimes found loaded with ſalited manganeſe (*p*).

Thus we have mentioned the fifteen metals which are known to be diſtinct, and have pointed out proceſſes by which the chief varieties of their ores may be examined in the humid way: the greater numbers of ways by which theſe bodies can be examined the better; now one method is neceſſary, now another. But I have no doubt that multiplied experiments will diſcover methods more numerous and effective than thoſe propoſed in the foregoing ſketch.

(*p*) The celebrated P. J. Hjelm diſcovered waters of this ſort about the lake Vettern.—Compare Mr. Scheele's Chemical Prælections, § 189. Obſ. 3.

DISSER-

DISSERTATION XXV.

OF THE

BLOW-PIPE;

And its Uſe in the Examination of Bodies, particularly Minerals.

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§ 1. *Introduction.*

THE tube which, from the uſes to which it has been applied, is called the ſoldering tube, or blow-pipe, is very uſeful and neceſſary to many artificers; but our countryman, the celebrated metallurgiſt Andreas Swab, was, if I miſtake not, the firſt who applied it to the examination of minerals, and that about the year 1738. This invention was afterwards much improved by

5 Meſſrs.

Meſſrs. Cronſtedt, Rinman, Engeſtroem, Quiſt, Gahn, and Scheele; nay, Mr. Engeſtroem has written an expreſs treatiſe upon its uſes, which was firſt publiſhed in Engliſh, afterwards tranſlated into the Swediſh, and finally the German language. The experience of many years has however ſhewn me, that this inſtrument is ſuſceptible of further improvement, both as to conſtruction and application: I ſhall therefore relate ſuch circumſtances concerning it as may be comprized in a brief deſcription.

§ II. *Figure of the Inſtrument:*

That which I uſe is formed of pure ſilver, leſt it ſhould be injured by ruſt; a ſmall addition of platina communicates the neceſſary hardneſs.

It conſiſts of three parts, which may occaſionally be joined: an handle A (tab. 2), terminating in a truncated conical apex a a, which may be, by twiſting, ſo adapted to the aperture b as to ſhut it more cloſely than can be done by a ſcrew. In the place of the hollow ſphere which is commonly uſed, I make uſe of the little box B, formed of an elliptical plate, ſo bended through the centre that the oppoſite ſides become parallel, and are joined round by a plate equal in breadth to c c: ſuch a box collects the moiſture of the breath as well as the ſphere, and

and is besides attended with the advantage of a compressed figure, and smaller circumference. The aperture (b) is somewhat conical, and hollowed out of the solid piece, and has no margin turned inwards, lest the efflux of the fluid, collected after long blowing, or the cleansing of the internal parts, should be in any degree prevented. The tube (c) is very small, and its shorter conical end (e e) exactly fitted to the aperture (f), so that no air can escape, unless through the orifice (g). Many of these tubes should be provided, with orifices of different diameters, to be applied on different occasions; the orifice (g) itself ought to be smooth and circular, otherwise the cone of flame, hereafter mentioned, will be divided (§ III.). The bands (h h, i i) prevent the conical apices (a a, e e) from being thurst in too far, and also serve another purpose; for when the conical apices (a a, e e), by repeated attrition, are at last so much diminished as to fall out spontaneously, by filing away a little of the bands, they may again be made tight. The figure represents the whole apparatus of the proper size.

§ III. *Method of blowing through the Tube.*

As it is absolutely necessary that the air should flow through the orifice in a continued stream, so long as the experiment continues

continues to require it, this labour will fatigue the lungs too much, unleſs an equable and uninterrupted inſpiration can at the ſame time be continued. To ſucceed in this operation without inconvenience, ſome labour and practice are neceſſary. The whole artifice, however, conſiſts in this, that while the air is inſpired through the noſtrils, that which is contained in the mouth be forced out through the tube by the compreſſion of the cheeks.

To ſome perſons this is extremely difficult; but frequent trials will eſtabliſh the habit, ſo that a continual ſtream of air can be ſupplied for a quarter of an hour and more, without any other inconvenience than the laſſitude of the lips compreſſing the tube.

§ IV. *The proper Kind of Flame.*

The ſtream of air above mentioned is neceſſary for impelling the flame upon the matter under examination. Too great a flame does not eaſily yield to the blaſt; and too ſmall a one produces a proportionably weak effect: a ſlender candle ſhould therefore be choſen (either wax or tallow) (D) with a cotton wick (k l). The burned top muſt be cut off at ſuch a length that the remainder may be bent a little (l m). The orifice (g) is to be held above, and near to this arch, perpendicular to (l m); and the air equably expreſſed.

The

The flame being forced to one ſide by the violence of the blaſt, exhibits two diſtinct figures; the internal figure (l n), conical, blue, and well defined; at the apex of this (n), the moſt violent degree of heat is excited; the external (l o), browniſh, vague, and undetermined, which is ſpoiled of its phlogiſton by the ſurrounding atmoſpheric air, and occaſions much leſs heat at its extremity (o) than the interior flame does.

§ V. *Proper Supports for the Matter under Examination.*

The ſubſtances to be examined, are ſupported by two different ſuſtentacula, according to the diverſity of the matters under conſideration; the one is charcoal of beech or fir, cut into the form of a parallelopiped; the other a ſilver, or (which is better) a golden ſpoon, fitted with a wooden handle. The firſt of theſe is generally uſed, except where phlogiſton is to be avoided, or the ſubject under examination is abſorbed by charcoal. The golden ſpoon ſhould be much leſs than the figure (E), as the bulk of the ſupport impedes the proper heat of the matter expoſed to examination.

Particles that are very ſmall and light are eaſily carried off by the blaſt of air; to prevent which a ſmall cavity ſhould be hollowed out in the charcoal, in which, being partly protected by another smaller piece of charcoal, they may be exposed to the apex of the flame.

§ VI. *Proper Fluxes.*

Substances which are not fusible *per se*, are often fused and dissolved by means of salts; I make use of three in particular, one of which is acid, another alkaline, and the third neutral.

1. The phosphoric acid, or rather the microcosmic salt, as it is generally called, which contains that acid partly saturated with mineral, partly with volatile alkali, and loaded besides with much water, and a gelatinous fat. This salt, when exposed to the flame, boils and foams violently, with a continual crackling noise, until the water and volatile alkali have flown off; afterwards it is less agitated, sending forth somewhat like black scoriæ, arising from the burned gelatinous part; these are soon dispelled, and exhibit a pellucid sphærule, encompassed by a beautiful green cloud, which is occasioned by the deflagration of the phosphorus arising from the extrication of the acid by means of the inflammable matter.

The clear globule which remains, upon the removal of the flame continues longer soft than that formed by borax, and therefore is more fit for the addition of the matter

ter

ter to be diſſolved. The volatile alkali is expelled by the fire, therefore an exceſs of acid ariſes in what remains, which eaſily attracts moiſture in a cool place.

2. The mineral alkali, or ſal ſodæ, which, when fuſed upon charcoal, melts ſuperficially, with a crackling noiſe, penetrates the charcoal, and diſappears: this, in the ſpoon, yields a permanent and tranſparent ſphærule, ſo long as it is kept fluid by the blue apex (n); but when the heat is diminiſhed puts on a milky opacity; hence it appears why this cannot be employed upon charcoal. This alkali attacks ſeveral ſubſtances, particularly ſiliceous matters.

3. Cryſtallized borax, expoſed to the flame upon charcoal, at firſt becomes opake, white, and wonderfully intumeſcent; it throws out branches and various protuberances; but when the water is expelled, it is eaſily collected into a maſs, which, when well fuſed, yields a colourleſs ſphærule, which retains its tranſparency even after cooling: if calcined borax be employed, the clear ſphærule is more ſpeedily obtained. This ſalt conſiſts of mineral alkali partially ſaturated with a peculiar acid, known by the name of ſedative ſalt; each of its principles is ſeparately fuſible, and each diſſolves a great number of other matters.

The habits of theſe ſalts, when expoſed to fire, being once known, it will be eaſy

 to

to underſtand the differences occaſioned by the different additions.

§ VII. *Circumſtances to be obſerved in the Examination of Bodies by the Blow-pipe.*

The exterior flame muſt firſt be directed upon the maſs under examination; and when its efficacy is well known, then the interior blue flame.

Particular care muſt be taken to obſerve whether the matter decrepitates, ſplits, ſwells, liquefies, boils, vegetates, changes colour, ſmokes, is inflamed, becomes oily, or magnetic, &c.

The piece expoſed to the flame ſhould ſcarcely ever exceed the bulk of a grain of pepper; but ought never to be ſo ſmall as not be taken up by the forceps (I); as, if it be too large, a part of it is neceſſarily without the focus, and muſt cool both the ſupport and the part immerſed in the blue apex. The particles may be ſufficiently comminuted upon the ſteel plate (G) by the hammer (F), and are prevented from being diſperſed by the ring (H).

A ſmall piece ſhould be added ſeparately to each of the fluxes, concerning which it muſt be obſerved, whether it diſſolves wholly, or in part only; whether this be effected with or without effervefcence; quickly or ſlowly; whether the maſs be divided into a powder, or gradually and externally corroded; what colour the glaſs is tinged; whether it be opake or pellucid.

Theſe general principles ſhall now be applied to exemplify the mineralogical and chemical uſe of the blow-pipe.

§ VIII. *Four Claſſes of Foſſils.*

Unorganized bodies are generally diſtributed into four claſſes; ſaline, earthy, inflammable, and metallic.

The ſalts are diſtinguiſhed by ſolubility and ſapor: but theſe properties differ in many ways as to degree, and in fact form a continued ſeries with the earths; ſo that the links in the chain of nature can ſcarcely be diſtinguiſhed, unleſs artificial limits be inſtituted.

Many of theſe, when expoſed to the flame, eaſily liquefy, or are diſſolved by the water of cryſtallization growing hot; but when this is expelled, ſplit, and, by a more intenſe heat, are really fuſed: others are deprived of their water without any motion, and are only once fuſible: ſome fly off by the heat.

Earths I call ſuch ſubſtances as are fixed in the fire, not ſapid, nor, though reduced to the moſt ſubtile powder, ſoluble in 1,000 times their weight of boiling water. Some of theſe, either by having their ſurfaces increaſed by a previous chemical diviſion, and their ſurface of contact thereby increaſed, or by the aſſiſtance of an exceſs of aerial acid, or by expoſure to intenſe heat in cloſe veſſels, actually are diſſolved in water; theſe I call ſaline earths: but the reſt, which can, by no artifice hitherto known, be made to enter water, deſerve the name of earths ſimply, and *κατ' ἐξοχην*. Examined by the blow-pipe *per ſe*, they are found either refractory or fuſible; and very few of them alone exhibit a tranſparent glaſs. They are diſſolved by the abovementioned fluxes, or at leaſt by one of them; beſides, they neither burn nor ſmoke.

Moſt of the inflammable ſubſtances burn, ſmoke, and yield coals loaded with an oily matter. Sulphureous bodies burn without any reſiduum; but ſome of theſe are only manifeſted by volatility.

The metals, excepting a few, are fuſible; the ignoble metals are calcined, and colour the fluxes.

§ IX. *Different Species of Salts.*

The ſalts, whether natural or factitious, are very eaſily examined by the blow-pipe. Some of theſe are properly called ſalts, conſiſting entirely of a ſoluble matter; ſuch are acids, alkalis, and the neutrals compoſed of theſe; but the others, containing a baſe not ſoluble *per ſe*, either earthy or metallic (which is not ſoluble in water, unleſs when united with a genuine ſalt) may be called middle or analogical ſalts.

§ x. *Acids.*

The acids which are always fluid I paſs over, as they elude the flame, and ſhall here only examine the concrete ſalts.

The acid of arſenic muſt be carefully diſtinguiſhed from white arſenic, which contains this acid indeed, but unites with ſo much phlogiſton, that it is coagulated (*a*) into a ſort of ſulphur. This acid, deprived of water, exhibits a dry maſs; and, expoſed in this ſtate to flame upon charcoal, receives from thence ſo much phlogiſton, as to regenerate white arſenic, and diffuſe a garlic odour. In the ſpoon it fuſes, and does not ſmoke, unleſs by the acquiſition of phlogiſton, either from the flame or the metallic ſupport.

The acid, which exiſts molybdæna (*b*), ſeems to be the radix of ſome metal; it is of a ſpecific gravity 3,461; poſſeſſes the property of tinging fluxes, and decompoſing phlogiſticated alkali.—Is this the acid of tin?

(*a*) See the Treatiſe on Arſenic.
(*b*) Mr. Scheele, Act. Stockholm, 1778.

This

This acid, expoſed to the flame upon charcoal, is abſorbed; in the ſpoon it emits a white ſmoke, which, upon contact of the interior cone, grows of a beautiful blue; but, expoſed to the exterior cone, again grows white: it tinges microcoſmic ſalt of an elegant green; borax, with a ſmall quantity of it, exhibits an aſhen colour by reflection, but by refraction a dark violet. No other acid tinges the fluxes.

The acid of borax, commonly called ſedative ſalt, eaſily liquefies, and in the ſame manner, but with far leſs intumeſcence than borax: it remains fixed in a pellucid globule (§ VI.).

The acid of tartar is not to be confounded with cream of tartar, which is partly ſaturated by the vegetable alkali (*c*): this liquefies upon the firſt contact of the exterior flame; ſoon is inflated, foams, grows black, and ſends forth a ſmoke and blue flame, leaving a ſpongy coal, which ſoon leaves white aſhes of a calcareous nature. In order to obſerve theſe changes diſtinctly, the combuſtion muſt be occaſioned ſlowly by the weakeſt part of the flame.

Cryſtallized acid of ſugar is by the exterior flame firſt made of an opake white, then flows, and finally ſoon flies off, without leaving any reſiduum.

(*c*) Act. Stockholm, 1770.

The

The acid of phoſphorus occurs in all the natural kingdoms; when dried it is eaſily fuſed, and aſſumes the form of a pellucid globule, which yet attracts the moiſture of the atmoſphere.

§ XI. *Alkalis.*

The cryſtallized vegetable alkali firſt becomes opake, and decrepitates long and violently, then melts into a globule which perſiſts in the ſpoon, but expands on the charcoal, and is abſorbed with a crackling noiſe.

The mineral alkali has the ſame properties as the ſal ſodæ deſcribed in § VI.

The volatile alkali liqueſies a little, and is diſſipated.

§ XII. *Neutral Salts.*

Several of the neutral ſalts flow twice, but, according to their different natures, exhibit different phænomena; which a few examples will ſufficiently illuſtrate.

The decrepitating Salts.

Theſe are broken and diſperſed by ſudden heat: of this ſort are vitriolated vegetable and volatile alkali, ſalited vegetable and mineral alkali.

Volatile

Volatile Salts,

Which have a baſe totally volatile, and generally fly off; vitriolated, nitrated and ſalited volatile alkali.

Genuine ſalt of amber by the exterior flame on the charcoal liquefies and ſmokes; by the interior takes fire, and in burning diſappears with a blue flame. In the ſpoon the ſame happens, except when the ſalt abounds with oil, which almoſt always happens: in this caſe ſome coaly veſtiges remain. The ſpurious ſalt of amber differs according to the frauds uſed in its preparation; it generally in the beginning ſwells, ſmokes, and grows black, then white; and finally, melts into a fixed white maſs.

Detonating Salts.

Theſe ſalts, which always abound with nitrous acid, liquefy in the ſpoon, and perſiſt even on the charcoal, unleſs it takes fire; for when ignited they immediately take fire on the contact of phlogiſton, ſending forth a violent flame, with a detonating noiſe. During this operation the acid is diſſipated, and the baſis, if fixed, remains alone. If the baſe be volatile, ſcarce any detonation is excited, for the ſalt flies totally off.

Nitrated vegetable alkali ſhews a blue flame, but the nitrated mineral and volatile alkali a yellow ore.

Carbo-

Carbonaceous Salts.

These, by the combuſtion of their acid, yield ſpongy coals, which, when ignited, ſoon grow white, leaving behind the alkaline baſe; ſuch are acid of tartar, crude tartar, ſal acetoſellæ, and tartarized vegetable and mineral alkali.

Hepatiſcent Salts.

These, expoſed to the flame on the charcoal, flow, and yield a yellow or red maſs, which diffuſes an hepatic ſmell, eſpecially when moiſtened by any acid. To this claſs belong all thoſe fixed in the fire, containing vitriolic acid, which, when ſaturated with the phlogiſton of the charcoal, generate ſulphur; theſe are vitriolated vegetable and mineral alkali.

§ XIII. *Middle earthy Salts.*

Of the middle earthy ſalts few flow ſo perfectly as to be reduced to a globule, nor do they all fuſe actually, though the water of cryſtallization in its departure excites a foam: thoſe which contain vitriolic acid efferveſce violently with borax and microcoſmic ſalt, but are difficultly diſſolved by ſal ſodæ.

Decrepitating Salts.

Gypſum ſpathoſum.

Intumeſcent

Intumescent Salts.

Vitriolated magnesia swells, foams, and, when repeatedly exposed to the flame, may be fused.

Alum is somewhat different; for, finally, all ebullition ceases, and the mass remains immoveably at rest, and it undergoes no other change than to split: when hot it is variegated with blue spots.

Acetated lime swells much like alum, but scarcely adheres to the charcoal.

Nitrated magnesia swells with a crackling noise, but without any detonation.

Salited magnesia in a dry state belongs to this class.

Fusible Salts.

Although gypsum eluded the force of fire in Pott's furnace, yet it may be fused in a moment, if a section of the lamella be exposed to the blue flame: though naturally pellucid, it instantly acquires an opacity — the water goes off without ebullition.

Carbonaceous Salts.

Tartarized lime and magnesia; nay, all the earths united with acid of tartar.

Soluble in Borax and Microcosmic Salt, with Effervescence.

Lime, magnesia, vitriolated clay, and acetated lime.

§ XIV. *Mid-*

§ XIV. *Middle metallic Salts.*

Some of the middle metallic ſalts, either containing a large quantity of water, or retaining pertinaciouſly the acid, flow in the fire, others only foam: moſt of them recover, at leaſt partly, their metallic appearance, eſpecially when they touch the coal, leaving at the ſame time a ſhapeleſs ſcoria. By the addition of borax the ſcoriæ are diſſolved and the regulus better collected, but here we conſider the ſalts alone: the fluxes are tinged in the ſame way as by the metallic calxes, § XXII. XXXV.

Decrepitating metallic Salts.

Nitrated lead, tartarized antimony.

Volatile metallic Salts.

To this belong the ſalts whoſe baſe is mercury, as they are diſſipated by fire; thoſe which contain marine acid in general fly off more quickly than thoſe which are loaded by any other menſtruum.

Detonating metallic Salts.

Silver, mercury, lead, and biſmuth, united with nitrous acid.

Intu-

Intumeſcent metallic Salts.

At the firſt approach of fire they ſwell with noiſe, and a certain ebullition, but then remain immoveable; vitriolated and nitrated copper, iron and cobalt vitriolated, vitriolated and nitrated zinc.

Fuſible metallic Salts.

Theſe are, by the exterior flame, eaſily reduced to globules. By this method ſilver and lead ſalited in the ſpoon put on the horny appearance, but by a long violent fuſion they again put it off, the acid being too much diminiſhed: hence it appears with what caution theſe metals are to be made horny in the crucible.

Silver and lead vitriolated, copper and zinc ſalited.

Carbonaceous metallic Salt.

Tartarized antimony.

Metallic Salts tinging the Flame.

Vitriolated copper, and alſo nitrated copper, produces a greenneſs; but ſalited copper acts with far more efficacy. The green cryſtals of this firſt grow red by the exterior flame; they ſoon liquefy, and grow black; they make the flame at firſt of a deep blue, which afterwards verges to a green. The flame

flame thus tinged expands much, and remains ſo until the whole maſs of the ſalt is diſſipated: this green ſalt, added to microcoſmic ſalt in fuſion, immediately ſhews a beautiful flame; the clear globule is tinged green, and does not grow opake or brown, unleſs a large quantity of the microcoſmic ſalt be added; a circumſtance which takes place much ſooner upon the addition of a ſmaller quantity of borax.

§ XV. *Different Species of Earths.*

Earths are in general either ſimple (which I call *primitive*) and incapable of decompoſition or mutual tranſmutation by any means hitherto known—of theſe five only have been as yet diſcovered—whether a ſixth exiſts in the diamond we are ignorant.

Thoſe are called *derivative* which ariſe from a mixture of two or more of the primitives. Many of thoſe which Mr. Cronſtedt thought to be ſimple, I have diſcovered, by the humid analyſis properly conducted, to be compound; this is not to be objected to that great mineralogiſt, as the chemical art at his time had not inveſtigated the treaſures of the mineral kingdom.

§ XVI. *Habitudes of the primitive Earths.*

Lime.

This (which by itſelf is infuſible) by a ſufficient degree of heat loſes its property of effervefcing in acids; it acquires folubility in water, the power of generating heat with it, and of fuffering fpontaneous calcination. Thefe laft properties however it lofes, if too much urged by heat. The heat it generates with water may eafily be tried by a drop of water on the back of the hand, with the addition of a fmall piece of lime juft cooled after burning.

Crude calcareous earth effervefces a little with mineral alkali, and is divided into fmall particles but fparingly diffolved; when overburned it feems not to be divided or diminifhed.

In borax the former diffolves with effervefcence, the latter fcarcely generates any bubbles.

In microcofmic falt the fame phænomena appear, but the effervefcence is fomewhat greater.

It is alfo obfervable that a very fmall piece of calcareous earth is eafily diffolved in borax and microcofmic falt, yielding fphærules altogether pellucid; but if more earth be gradually added, the flux, at length faturated, retains the diffolved matter, indeed, while in perfect fufion; but on removing the flame, the part which was taken up by means of the heat alone, feparates; from hence clouds arife at firft, and the whole globule becomes opake, and recovers its tranfparency again by fufion. This is entirely correfpondent to what happens in the humid

humid way: for warm water, ſaturated with nitre, or Glauber's ſalt, upon cooling is obliged to depoſit that part which it had taken up in virtue of its warmth. If the fuſed pellucid globule (which would grow opaque upon cooling) be quickly plunged into melting tallow, water, or other ſubſtance, hot (for cold generally cracks it) ſo as to grow ſuddenly hard, it retains its tranſparency, the particles being as it were fixed in that ſtate which is neceſſary to tranſparency. This is a phænomenon highly worthy of obſervation, which cannot be ſeen in the crucible.

Terra Ponderoſa.

Terra ponderoſa, expoſed alone to the flame, becomes, like calcareous earth, cauſtic, ſoluble in water, and non-efferveſcent in acids.

In ſal ſodæ it efferveſces only a little, but is ſenſibly diminiſhed.

In borax it diſſolves with ſlight efferveſcence.

As alſo in microcoſmic ſalt; but here it efferveſces ſomewhat more violently.

The phænomena obſerved on ſaturation with calcareous earth, have place here alſo.

Magneſia, ignited alone, loſes its aerial acid, together with the property of efferveſcing in acids.

In ſal ſodæ it efferveſces a little, but is ſcarcely diminiſhed.

In borax it diſſolves with a ſlight efferveſcence.

As alſo in microcoſmic ſalt, but with a more violent motion.

Clay.

Common argillaceous earth abounds with heterogeneous particles, and always contains a conſiderable quantity of ſiliceous earth, at leaſt, which generally amounts to half; hence, when clay is required pure, as in this inſtance, the earth of alum, digeſted in an alkaline lixivium, and well waſhed, muſt be employed.

Expoſed to the flame it grows hard, contracts its bulk, but does not fuſe.

In ſal ſodæ it efferveſces a little, but is ſparingly diſſolved.

In borax it diſſolves with remarkable efferveſcence.

In microcoſmic ſalt a ſtill more violent ebullition takes place.

Siliceous Earth.

Alone it is not fuſed.

Sal ſodæ diſſolves it with violent efferveſcence; and if the ſiliceous earth diſſolved exceeds the weight of the flux, it yields a pellucid glaſs. This, and all the other operations with ſal ſodæ, muſt be performed in the ſpoon.

In borax it diſſolves ſlowly, without any ebullition.

In microcofmic falt very flowly, and without effervefcence.

§ XVII. *Derivative Earths.*

To avoid confufion from multiplicity, we fhall collect thefe into claffes, according to their moft remarkable habits.

Decrepitating.

Spathous mineral fluor.
Lapis ponderofus (*d*).
Calcareous fpar. Spathum ponderofum.
The decrepitation may be performed without fcattering, in a glafs tube clofed by the finger, and held over the flame.

Infufible.

Diamond. Pure Afbeftos *. Refractory clay*. Hyacinth. Hydrophanous filiceous jafper.
Lapis ponderofus.
Pure mica *.

(*d*) This is the name given by Mr. Cronftedt (§ 209) to a foffile, which he enumerates among the ores of iron, and which poffeffes a peculiar fpecific gravity. I have attempted the analyfis of this mineral, and have difcovered in it lime united to a fpecies of acid hitherto unknown; this acid, if I miftake not, is the radix of fome metal. There is alfo prefent a portion of iron, which is indeed but feldom wanting in minerals. The fpecific gravity of this acid, and its habitudes with fluxes, and phlogifticated alkali, indicate its metallic nature;—but we fhall elfewhere treat of this matter more at large.

Quartz.
Ruby.
Sapphire. Flint. Steatite *.
Topaz.

Thoſe four marked with a * are indurated by fire.

Infuſible, changing Colour.

Bolar earths generally grow black—lime, mixed with aerated magneſia, black; lime, blackened by ſubtle bitumen, white.

Of the gems ſome change or loſe colour; theſe are, the cryſolith, topaz, and ſometimes the ſapphire.

The red and green jaſper acquire a whitiſh or grey colour.

Green, black, and red ſteatite grow white.

Fuſible without Ebullition.

Martial aſbeſtos. Augites (aqua marina*).
Baſaltes.
Chryſolith *.
Mineral fluor.
Granite.
Marga.
Petroſilex.
Emerald *.
Spathum ponderoſum (this corrodes the charcoal, and acquires an hepatic taſte).
Spathum pyromachum.
Trapp.

The earths marked with a * do not, but with

with great difficulty, ſhew any ſigns of fuſion.

Fuſible with Ebullition.

Lithomarga.
Schoerl (*e*).
Turmalin. The inflated ſcoria quickly grows white, though the ſtone is brown.
Zeolith.

Fuſible altogether in Sal Sodæ, and with Efferveſcence.

Achates.
Chalcedony. Cornelian. Cos turcica *.
Mineral fluor *.
Onyx. Opal.
Quartz.
Common flint. Spathum ponderoſum.
Thoſe marked (*) efferveſce but little.

Diviſible with or without Efferveſcence in Sal Sodæ, but not entirely ſoluble.

Amianthus. Aſbeſtos.
Baſaltes.
Chryſolith * (*f*).

(*e*) I uſe the names *ſchoerl* and *trapp*, which are now known all through Europe. By *baſaltes* I underſtand larger priſms, which compoſe the Giant's Cauſeway, Staffa, and other columnar mountains.

(*f*) The yellowiſh cryſtalline matter which fills up the interſtices of the native Siberian iron, exhibits the ſame properties with reſpect to fire as the chryſolith.

 Garnet

Garnet *.
Hornblende.
Jaſper.
Lapis ponderoſus. Lithomarga.
Mica. Matrix of the alum of Tolfa.
Petroſilex.
Aluminous ſchiſt. Tegular ſchiſt of Helſing. Emerald. Spathum pyromachum. Steatites.
Talc. Trapp. Trippel. Turmalin.

Not fuſible or diviſible by Sal Sodæ.

Diamond.
Hyacinth.
Ruby.
Sapphire.
Topaz.

Soluble in Borax, with more or leſs Efferveſcence.

Mineral fluor *.
Marga. Mica *. Ore of Tolfa.
Aluminous ſchiſt. Tegular ſchiſt of Helſing *.
Spathum ponderoſum. Schoerl.
Talc. Turmalin.
Thoſe marked * efferveſce but little.

Soluble in Borax, without Efferveſcence.

Achates. Diamond. Amianthus. Aſbeſtos.
Baſaltes.

Chalcedony.

Chalcedony. Cornelian. Chryſolith. Cos turcica.

Garnet.

Hyacinth. Hydrophanous ſiliceous jaſper.

Lapis ponderoſus. (The flux grows hardly blue ; on too much cooling it becomes white and opake).

Lithomarga.

Onyx. Opal.

Petroſilex.

Quartz *.

Ruby.

Sapphire. Common flint *. Emerald. Steatite. Spathum pyromachum.

Trapp. Trippel. Topaz *.

Zeolith.

Thoſe marked * require a greater quantity of flux, and longer heat, than the reſt.

Soluble in Microcoſmic Salt, with more or leſs Efferveſcence.

Baſaltes *.

Cos turcica.

Mineral fluor *.

Lapis ponderoſus.—It efferveſces at firſt, then ſcarcely diſſolves: the flux acquires a fine blue tinge, without any mixture of redneſs. The colour is diſcharged by the exterior flame, or by a ſmall quantity of nitre, but is reſtored by the interior flame; if the proportion of earth be large it it acquires a pellucid brown colour, not dischargeable either by nitre or the flame; if still larger, it grows black and opake.

Marga. Mica *. Aluminous ore of Tolfa.

Aluminous schist. Tegular schist of Helsing *. Schoerl. Spathum ponderosum.

Turmalin*.

Those marked * effervesce but little.

Soluble in Microcosmic Salt, without Effervescence.

Agate. Diamond. Amianthus. Asbestos.

Chalcedony *. Cornelian *. Crysolith *.

Granite.

Hornblende. Hyacinth. Hydrophanous siliceous jasper *.

Lithomarga.

Onyx *. Opal *.

Petrosilex.

Quartz *.

Ruby.

Sapphire. Common flint. Emerald. Steatites.

Spathum pyromachum.

Talc. Topaz. Trapp. Trippel.

Zeolith.

Those marked * are more difficultly dissolved than the rest, and scarce sensibly.

In general it is to be obſerved, 1ſt, that when the efferveſcence is to be examined, only a very ſmall piece of the matter is to be added to the flux, as the moſt ſubtile powder contains air, which, being expelled by the heat, forms the appearance of efferveſcence. 2d, That the ſolution is often accelerated by lime, ſpathum ponderoſum, gypſum, and other additaments, both in borax and microcoſmic ſalt. 3d, That gypſum alone is ſometimes an excellent and very uſeful flux. This ſalt, with an equal portion of fluor mineral, is eaſily reduced to a pellucid globule, which yet, upon cooling, grows white and opake. The ſpathum ponderoſum alſo unites with mineral fluor, but the maſs does not become pellucid.

§ XVIII. *Different Species of inflammable Subſtances.*

The whole theory of inflammation depends upon that ſubtile principle which goes by the name of phlogiſton; but this, ſo far as is yet known, can never be collected pure and alone, but always requires a ſuitable baſe, to which it muſt be connected, in order to become manageable. Scarce any body exiſts entirely deſtitute of it, but a certain accumulation of it is neceſſary for deflagration; this accumulation takes place in ſpirit of wine, in oils, in ſulphur, in zinc,

zinc, arſenic, and perhaps in tin. It is alſo neceſſary that its connection ſhall be ſo looſe that the circumambient pure air may diſſolve the union.

The dry inflammable ſubſtances, which alone are here to be conſidered, are of two kinds; viz. either coagulated and indurated oils, which are commonly called bitumens, or an acid ſaturated with phlogiſton, ſuch as ſulphur. Some of the bitumens are pure, ſuch as aſphaltus, ambergris, and amber; others reſiding in a copious earthy baſe: hence we have mountain pitch, bituminous ſchiſts, and lithanthraces.

Vitriolic ſulphur is ſeldom found alone: it readily unites with other matters, eſpecially metals; and hence reſult mineralizations, which belong the more expreſsly to metals, as it is certain that they are very ſeldom inflammable.

§ XIX. *Habitudes of inflammable Subſtances in the Fire.*

Moſt of the inflammable ſubſtances, when expoſed to the apex of the flame, begin to liquefy, unleſs entangled in much earth, which yet does not always prevent their inflammation: when they are once inflamed let the blaſt be ſtopped until they have burned away, either alone or with a flux; and the reſiduum, if any, be examined afterwards by the flame.

Ambergris

Ambergris burns with a white odoriferous and ſmoky flame; when very pure it is totally conſumed by degrees, but when impure it is extinguiſhed, leaving behind a black maſs, which ſoon grows white by ignition, and conſiſts partly of a calcareous powder.

Tranſparent amber exhibits almoſt the ſame habits, but by heat in the ſpoon it vaniſhes totally; ſo that this way we can hardly form any judgment concerning a reſiduum, which yet is eaſily obtained from opake amber.

Pure aſphaltus burns with a ſmoke, and is totally conſumed, without any reſiduum.

Mountain pitch leaves black ſcoriæ, ſhining and brittle.

Bituminous ſchiſt and lithanthraces, beſides their matrix, leave an oily coal, or even ſpongy ſcoriæ, if the reſiduum liquefies at all.

Common ſulphur readily fuſes alone, and grows red; it takes fire, and is conſumed with a blue flame, and a moſt penetrating ſuffocating odour.

Molybdæna contains a portion of common ſulphur united to a peculiar (*g*) acid. This does not take fire, and upon the charcoal ſuffers little change; but, expoſed to the flame in the ſpoon, it depoſits a white ſmoke

(*g*) Mr Scheele, Act Stockholm, 1777.

in

in the direction of the blast; this smoke, by the contact of the interior cone, grows blue, but loses its colour by the exterior cone: it is scarcely changed by borax and microcosmic salt, but dissolves in sal sodæ with violent effervescence; on fusion it grows red and transparent; on cooling, dilutely red and opake, and has an hepatic smell.

Plumbago, another species of sulphur, contains aerial acid loaded with phlogiston (*h*); on burning it smokes, but the smoke is only seen at the instant the flame ceases. It differs from molybdæna in this, that it deposits no white powder, and particularly in not being taken up by sal sodæ; it is not changed by borax or microcosmic salt.

The ores which are called inflammable, take fire difficultly; some of them are scarcely changed, others are consumed or fly off, leaving the metallic calx behind.

In general the fluxes are tinged by phlogiston; but unless this volatile principle be fixed by some metallic calx, the tinge is easily destroyed by burning.

(*h*) Mr. Scheele, Act Stockholm, 1777.

§ xx. *Dif-*

§ XX. *Different Forms under which Metals appear.*

The metals are diſtinguiſhable from all other ſubſtances by their peculiar ſplendor and ſuperior ſpecific gravity: they occur in the boſom of the earth in three different ſtates, either altogether in a metallic form, in which caſe they are called *native*; or ſimply deprived of phlogiſton, and reſembling earths, when they are denominated *calciform*; or, finally, diſſolved by ſulphur or acids, on which occaſion they take the appellation of *mineralized*. Each of theſe forms ſhall be ſeparately conſidered.

§ XXI. *Various Habits of Metals in the Fire.*

The metals expoſed to the flame do not all ſhew the ſame habits.

The perfect metals do not, even in the moſt intenſe heat, loſe a ſenſible quantity of their phlogiſton; and when calcined in the humid way recover their former nature ſimply by fuſion.

The imperfect metals are calcined by fire, eſpecially by the exterior flame, and then, in order to being reduced, indiſpenſably require the contact of a phlogiſtic ſubſtance.

With reſpect to fuſibility, mercury forms one extreme, as it fuſes in the ordinary tempe-

temperature of the atmoſphere, it cannot therefore be hardened but by artificial cold, and is always in fuſion, always fluid; the reſt follow in this order: tin, biſmuth, lead, zinc, antimony, ſilver, gold, arſenic, cobalt, nickel, iron, manganeſe, and finally platina, which forms the other extreme, as it ſcarcely fuſes but in the focus of a burning mirror; all theſe, the two laſt excepted, yield to the blow-pipe without any additament. Forged iron indeed is not melted without difficulty, but fuſed iron perfectly.

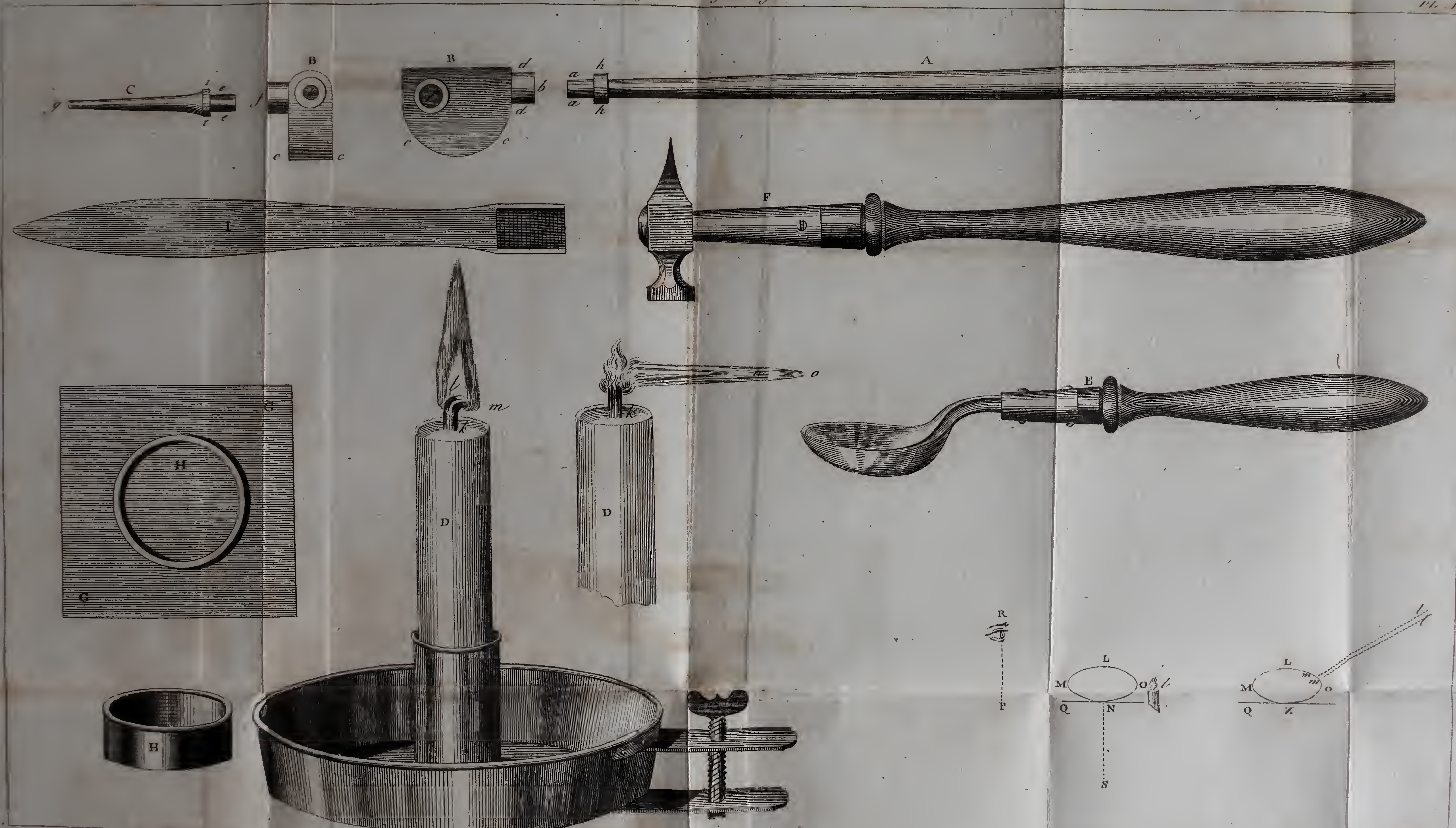
With reſpect to fixity, ſome fly off altogether, others are partly and ſlowly reſolved into ſmoke.

Metals in fuſion affect a globular form, and therefore eaſily roll off the charcoal, eſpecially if they are of the ſize of a grain of pepper; therefore, either ſmaller pieces ſhould be uſed, or they ſhould be placed in excavations made in the ſurface of the charcoal. On firſt fuſing they aſſume a poliſhed ſurface, an appearance which the perfect metals always retain: but the imperfect are ſoon obſcured by a calcined pellicle; for the ſurrounding air attracts the phlogiſton with great avidity, eſpecially when aſſiſted by heat, which yet alone is not able to expel that principle.

The colours communicated to the calxes by fire vary.

Some of the calxes eaſily recover their metallic form ſimply by expoſure to flame

upon



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upon the charcoal; others are reduced in this way with difficulty, and ſome not at all.

The reduced calxes of the volatile metals immediately fly off.

In the ſpoon they exhibit nitrous globules, but it is very difficult to prevent them from being firſt diſſipated by the blaſt.

With Fluxes.

The metals are taken up by the fluxes; but as ſal ſodæ yields an opake ſphærule, we neglect it.

Globules of borax, upon the addition of any metallic calx, diſſolve and fuſe it, and, unleſs too much loaded, appear coloured and pellucid. A piece of metal calcined in the flux produces the ſame effect, but more ſlowly.

A portion of the calx generally recovers its metallic form, and floats upon the ſurface, like one or more excreſcences.

In proportion as the globule is more loaded, it more readily ſpreads upon the charcoal, and at length cannot be formed into a globule; for the metallic additament increaſes the attraction for phlogiſton.

The calxes of the perfect metals are reduced by borax in the ſpoon, and adhere to it at the point of contact, and there only.

The microcoſmic ſalt acts like borax, but does not reduce the metals; it attacks them more powerfully on account of its acid nature; at the ſame time it preſerves the ſphærical form, and is conſequently adapted in a peculiar manner for the examination of metals.

The tinge communicated to the flux frequently varies, being different in the fuſed and the cooled globule, and that in a double and altogether different manner; for ſome of the diſſolved calxes, while fuſed, ſhew no colour, but acquire one on cooling; others, in the ſtate of fluidity, have a much more intenſe colour. If too great a concentration of colour injures the tranſparency, the globule, on compreſſing it with the forceps, or drawing it out into a thread, will exhibit a thin and tranſparent maſs; but if the opacity ariſes from ſuperſaturation, this artifice will not ſerve, but more flux muſt be added. No metal, unleſs calcined, communicates a tinge. As the fluxes attract the metals with unequal forces, theſe laſt precipitate one another.

Metals, mineralized by acids, poſſeſs the properties of metallic ſalts; and thoſe loaded with aerial acid that of calxes, as this ſubtile menſtruum is eaſily expelled without any efferveſcence; but when loaded with ſulphur they poſſeſs properties of a peculiar kind. They may be fuſed, nay calcined, upon the charcoal, as alſo in a golden or well-gilded ſilver ſpoon. The volatile are diſtinguiſhable by the ſmell or ſmoke, the fixed reſidua, by the particles reduced or pre-

cipitated

cipitated upon iron, or from the tinge of the fluxes. We ſhall now examine the more ſimple caſes, and treat of the more complex in another Work (*h*).

§ XXII. *Gold in a reguline State.*

Reguline gold fuſes upon the charcoal, and is the only one which remains unchanged.

Calcined.

That gold may be deprived of its phlogiſton in the humid way, has been already ſhewn; this calx may be reduced by fire alone (§ XXI.); but that this calcination may alſo be effected by fire is ſeen from the ruby-coloured glaſs, which may be made, even by the blow-pipe, in the following way:

To a globule of microcoſmic ſalt let there be added a ſmall piece of ſolid gold, of gold leaf, of purple mineral, or (which is beſt) of the cryſtalline ſalt formed by a ſolution of gold in aqua regia in which ſea-ſalt is contained; let this be again fuſed, and added, while yet ſoft, to turpeth mineral, which immediately grows red on the warm contact. The fuſion being afterwards repeated, a vehement effervescence ariſes; when this is conſiderably diminiſhed let the blaſt be ſtopped for a few

(*h*) Sciagraphia Regni Mineralis.

moments, again begun, and ſo continued, until almoſt all the bubbles diſappear. After this ſometimes the ſphærule, on cooling, aſſumes a ruby colour; but if this does not happen, let it be juſt made ſoft by the exterior flame, and upon hardening this tinge generally appears. If the proceſs ſhould fail at firſt, owing to minute circumſtances which cannot be deſcribed, it will ſucceed on the ſecond or third trial. The ruby-coloured globule, if compreſſed by the forceps while ſoft, often becomes blue; by ſudden fuſion it generally aſſumes an opal colour, which by refraction appears blue; by reflection, a brown red: but if further urged by the fire it loſes all colour, and appears like water; yet the redneſs may be re-produced ſeveral times, by the addition of turpeth mineral.

In the ſame way the flux is reddened by calx of tin, in the place of the turpeth; but it has a yellowiſh hue, and, beſides, more eaſily contracts opacity. The redneſs communicated by turpeth mineral is of a purple ſort, altogether like that of a ruby.

Borax produces the ſame phænomena, but more rarely. It muſt alſo be obſerved, that the ſlighteſt variation in the management of the fires often makes this experiment fail.

As the ruby colour may alſo be produced by copper (§ XXVII.), a doubt may ariſe, whether it be the gold, or the remains of the copper (which cannot be completely ſeparated either by antimony or nitre) which in this

this case produces the red colour: but it is not improbable that both metals may occasion the same colour; besides, copper is often found to contain gold.

Mineralized Gold.

Gold cannot be directly united with sulphur; but by means of iron, which attracts both strongly, they are sometimes found united into a golden pyrites: but as the quantity of gold is very small, a visible globule can scarcely be extracted by fusion and scorification by the blow-pipe.

I have as yet had an opportunity of examining the ore of Nagyay only imperfectly:—upon the charcoal it smokes a little, liquefies, and finally yields a white globule, bright like silver, and malleable;—a yellow cloud is observed about it. Borax takes it up without effervescence or tinge; but microcosmic salt, with effervescence, and of a brownish red; but by long fusion the tinge is discharged, and cannot be brought back, either by the exterior flame or nitre. A metallic globule like the former floats in the flux.

§ XXIII. *Platina.*

Native grains of platina do not at all yield to our fire, either alone or mixed with fluxes, which yet it often tinges of a green colour;

 but

but platina, precipitated from aqua regia by vegetable or volatile alkali, is reduced by microcoſmic ſalt to a ſmall malleable globule; ſeven or eight of theſe, flattened by the hammer, I have been able to bring together to a malleable maſs; but more only yielded a brittle one. Platina ſcarcely loſes all its iron, unleſs reduced to very thin fuſion; hence it eaſily appears how difficult the depuration of a large maſs muſt be.

§ XXIV. *Silver, reguline.*

Reguline ſilver eaſily liquefies, and reſiſts calcination.

Silver-leaf, faſtened to a thin glaſs by means of the breath, or a ſolution of borax, may eaſily be fixed on it by the flame, and, what is remarkable, through the glaſs it appears of a gold colour; but care muſt be taken not to crack the glaſs.

Calcined Silver.

Calcined ſilver, precipitated from nitrous acid by fixed alkali, is eaſily reduced.

The microcoſmic ſalt diſſolves it quickly and copiouſly, but upon cooling it grows opaque, of a whitiſh yellow, which is alſo ſometimes the caſe with leaf-ſilver; if copper be preſent it is diſcovered by a green colour, and ſometimes by a ruby tinge, unleſs

leſs we rather chuſe to impute that to gold. The globules can ſcarcely be got pellucid, except the quantity of calx be very ſmall, but with borax a longer fuſion is neceſſary to obtain an opacity.

The globule loaded with diſſolved ſilver, during fuſion in the ſpoon, covers a piece of copper added to it with ſilver, and becomes itſelf of a pellucid green : antimony ſpeedily takes away the milky opacity of diſſolved luna cornea, and ſeparates the ſilver in diſtinct grains. Cobalt, and moſt of the other metals, alſo precipitate ſilver in the ſame way as by the humid method ; i. e. a double elective attraction takes place. The metal to be diſſolved remains untouched ſo long as it retains all its phlogiſton ; but is taken up when a ſufficient quantity of that principle has ſhifted to the precipitate, and reduced it.

Mineralized Silver.

Silver, mineralized by marine and vitriolic acid, yields a natural luna cornea, which upon the charcoal produces a number of ſmall metallic globules : it diſſolves in microcoſmic ſalt, and renders it opake : it is reduced, at leaſt partially, by borax.

Sulphurated ſilver (the glaſſy ore of ſilver) fuſed upon the charcoal, eaſily parts with the mineralizing ſubſtance ; ſo that a poliſhed globule is often produced, which, if neceſſary, may be depurated by borax : the ſilver may alſo be precipitated by the addition of copper, iron, or mangaaneſe.

If arſenic be alſo preſent (as in the red ore of ſilver) it muſt be firſt freed from the ſulphur by gentle roaſting; and finally entirely depurated by borax: it decrepitates at firſt.

Copper, together with ſulphur and arſenic, mixed with ſilver (the white ore of ſilver) yields a regulus containing the ſame alloy.

Lead, loaded with ſulphur and ſilver (galena) is to be freed in the ſame way from the ſulphur, after which the lead is gradually diſſipated by alternately fuſing and cooling, or is ſeparated in a cupel from the ſilver, by means of flame. In galena I have not yet been able to precipitate the ſilver diſtinct from the lead, but the whole maſs becomes malleable: the ſame is true of tin, but the maſs is more brittle.

§ XXV. *Mercury.*

Pure mercury upon the charcoal flies off by a moderate heat, the fixed heterogeneous matters (if any there be) remaining behind.

When calcined it is eaſily reduced and diſſipated: the fluxes take it up with effervеſcence, but it is ſoon all driven off.

I have never yet had an opportunity of examining mercury, naturally mineralized by acids, but this is undoubtedly volatile.

When

When loaded with ſulphur it liquefies upon the charcoal, ſhews a blue flame, ſmokes, and gradually diſappears; but if cinnabar be expoſed to the blow-pipe upon poliſhed copper, the mercurial globules are fixed all around.

§ xxv. *Lead, reguline and calcined.*

As the imperfect metals are eaſily calcined, we ſhall conſider lead under the two forms, *viz.* reguline and calcined.

Lead readily fuſes, and continues for ſome time to retain a metallic ſplendor; by a more intenſe heat it boils and ſmokes; hence a yellow circle is formed upon the charcoal. It communicates a ſcarce viſible yellow colour to fluxes; and when the quantity is large, the globule, on cooling, contracts a white opacity more or leſs perfect: when diſſolved it is not precipitated by copper. The metals do not precipitate it from ſulphur in the ſame order as from acids.

Lead united to aerial acid, on the firſt touch of the flame grows red; when the heat is encreaſed it flows, and is reduced to numberleſs minute globules. When united with phoſphoric acid it fuſes, and yields an opaque globule, but is not reduced. With fluxes it ſhews the ſame habits as calx of lead.

Mineralized Lead.

Sulphurated lead (galena) eaſily liquefies, and,

and, being gradually deprived of the volatile part, yields a diſtinct regulus, unleſs too much loaded with iron. It may be precipitated by iron and copper.

§ XXVI. *Copper, reguline and calcined.*

A ſmall piece of copper, either ſolid or foliated, ſometimes communicates a ruby colour to fluxes, eſpecially when aſſiſted by tin or turpeth mineral (§ XII.): if the copper be a little more or a little further calcined, it produces a green pellucid globule, the tinge of which grows weaker by cooling, and even verges to a blue. By long fuſion with borax on the charcoal (but hardly in the ſpoon) all the colour is at length deſtroyed, and can ſcarcely be re-produced by nitre, but this colour remains fixed with microcoſmic ſalt. If the calx, or metal to be calcined, during fuſion is added in conſiderable quantity, upon cooling it acquires an opake red, although, while fuſed, it is pellucid and green; by a ſtill larger quantity it contracts opacity, even while in fuſion, and upon cooling a metallic ſplendor. Veſtiges of copper, ſo faint as ſcarcely to tinge the flux, precipitate a viſible pellicle upon a piece of poliſhed iron added to it during ſtrong fuſion, and the globule in its turn takes the colour of iron; in this way the ſmalleſt portions of copper may be diſcovered.

The

The globule made green by copper, fuſed in the ſpoon with a ſmall piece of tin, until the colour is diſcharged, yields a ſphærule of tin, mixed with copper, very hard and brittle: in this caſe the precipitated metal pervades the whole of the maſs, and does not adhere to the ſurface.

Cobalt precipitates the calx of copper, diſſolved in the ſpoon by flux, in a metallic form, and imparts its own colour to glaſs, which nickel cannot do. Zinc alſo precipitates it ſeparately, and rarely upon its own ſurface, as its fuſion can ſcarcely be avoided.

Mineralized Copper.

Copper loaded with aerial acid, at the firſt touch of the flame grows black, and fuſes in the ſpoon: on the charcoal the lower part, which touches the ignited ſupport, is reduced.

When loaded with a ſuperabundance of marine acid it tinges the flame (§ XIV.); but with a ſmall quantity it ſhews in that way no appearance of the metal. Thus the beautiful cryſtals of Saxony, which are cubic and of a deep green, do not tinge the flame; they impart to microcoſmic ſalt a pellucid greenneſs, I could not obtain with that ſalt an opaque redneſs, although this colour is eaſily produced in a globule of borax.

Copper ſimply ſulphurated (aſhen ore of copper) when cautiouſly and gently roaſted

by

by the exterior flame, finally by fusion yields a regulus surrounded by a sulphurated crust; the mass, roasted with borax, separates the regulus more quickly.

When iron is present, but in small quantity, the piece to be examined must be first roasted; let it then be dissolved in borax, and tin added to precipitate the copper. The regulus may also be obtained by sufficient calcination and fusion, even without a precipitant, unless the ore be very poor.

When pyrites contain copper, though less than 0,01 of their weight, yet its presence may be detected by these experiments in small: let a grain, the size of a flax-seed, be roasted, but not so much as to expel all the sulphur; let it be then well dissolved by borax, a polished rod of iron added, and the fusion continued until the surface, when cooled, loses all splendor. So much borax is required as will be sufficient to make the whole of the size of a grain of hemp-seed. Slowness of fusion is injurious, and by too great tenuity the precipitation is retarded; this may be corrected by the addition of a little lime: too much calcination is inconvenient, for by this the globule forms slowly, is somewhat spread, becomes knotty when warm, corrodes the charcoal, destroys the iron, and the copper does not precipitate distinctly;—this defect is amended by a small portion of the crude ore.

When

When the globule is properly fuſed, as directed, immediately upon ſtopping the flame let it be thrown into cold water, in order to break ſuddenly: if the cupreous content be leſs than 0,01, one end of the wire only is covered with copper, which otherwiſe would be entirely covered.

The celebrated Gahn, who has examined copper ores with peculiar accuracy, has another method of diſcovering the ſmaller traces of that metal; namely, a grain of the ore, well freed from ſulphur by calcination, is expoſed to the action of the flame, driven ſuddenly upon it, *per vices*; and at theſe inſtants a cupreous ſplendor appears upon the ſurface, which otherwiſe is black; and this ſplendor is the more quickly produced, in proportion as the ore is poorer.

Cupreous pyrites on roaſting tinges the flame green.

§ XXVII. *Iron, reguline and calcined.*

Forged iron is calcined, but can ſcarcely be fuſed, and when fuſed liquefies.

Forged iron cannot be fuſed by borax; it fuſes in microcoſmic ſalt, but is rendered brittle.

Calcined iron, by heating on the charcoal, becomes magnetic—in the ſpoon it fuſes.

The fluxes grow green with this metal; but in proporton as the phlogiſton is more

 deficient

deficient they grow more of a browniſh yellow: on cooling the tinge is much weakened; nay, when originally weak, entirely vaniſhes. By too much ſaturation the globule becomes black and opake.

The ſulphureous pyrites may be collected into a globule by fuſion, and is firſt ſurrounded by a blue flame; but as the metal is eaſily calcined, and changes into black ſcoriæ, neither by itſelf, nor with fluxes, does it exhibit a regulus;—on roaſting it grows red.

§ XXVIII. *Tin, reguline and calcined.*

Tin eaſily liquefies, and is calcined.

The fluxes diſſolve the calx ſparingly; and, when ſaturated, contract a milky opacity. Some ſlight veſtiges of this metal, diſſolved in any flux, may be diſtinctly precipitated upon iron.

Cryſtallized ore of tin, urged by fire upon the charcoal, yields its metal reduced.

§ XXIX. *Biſmuth, reguline and calcined.*

Biſmuth has nearly the ſame habits as lead; the calx is reduced upon the coal, it is fuſed in the ſpoon.

The calx, diſſolved in microcoſmic ſalt, yields a browniſh yellow globule, which grows

grows more pale upon cooling, at the ſame time loſing ſome of its tranſparency: by too much calx a perfect opacity is produced.

A ſimilar maſs is obtained with borax in the ſpoon; but on the coal a grey one, which can ſcarcely be freed from bubbles. On fuſion, the glaſs ſmokes, and forms a cloud about it.

Biſmuth is eaſily precipitated by copper and iron.

Mineralized Biſmuth.

Sulphurated biſmuth is eaſily fuſed, exhibiting a blue flame and a ſulphureous ſmell. Cobalt, when added, by means of the ſulphur, enters the globule; but the ſcoria ſoon ſwells into diſtinct partitions, which, further urged by fire, exſudes globules of biſmuth.

Sulphurated biſmuth, by the addition of borax, may be diſtinctly precipitated by iron or manganeſe.

§ XXX. *Nickel, reguline and calcined.*

The regulus of nickel fuſed is indeed calcined, but more ſlowly than other metals.

The calx imparts to fluxes an hyacinthine colour, which on cooling grows yellow, and by long-continued fire may be deſtroy-ed; if the calx of nickel is contaminated by ochre of iron, the latter is firſt diſſolved. Nickel diſſolved is precipitated on iron, nay on copper—an evident proof that it does not originate from either of theſe metals.

Mineralized Nickel.

Sulphurated nickel is no where found without iron and arſenic: the regulus is obtained by roaſting, and fuſing with borax, though it ſtill remains mixed with ſome other metals.

§ XXXI. *Arſenic, reguline and calcined.*

Regulus of arſenic kindles by a ſudden heat, and not only depoſits a white ſmoke on the charcoal, but diffuſes the ſame copiouſly all around. The calx ſmokes with a garlic odour, but cannot burn.

By a proper quantity the fluxes grow yellow, without opacity; and by a long-continued fire the volatile additament is diſpelled. Iron and copper precipitate this ſemi-metal under a metallic form, which gold is not able to do.

Yellow arſenic liquefies, ſmokes, and tototally flies off: when heated by the exterior flame, ſo as neither to liquefy nor ſmoke, it grows red, and again, upon cool-

ing,

ing, yellow; if it only begins to fuſe, it acquires a red colour, which remains after cooling. Realgar liquefies more eaſily, and is beſides totally diſſipated.

§ XXXII. *Cobalt, reguline and calcined.*

The regulus of cobalt fuſes, and may partly be depurated by borax, for the iron is firſt calcined and taken up. The ſmalleſt portion of the calx tinges the flux of a deep blue, which yet, when ſeen by refraction, appears violet: this colour is very pertinacious in the fire. Cobalt is precipitated upon iron from the blue globule, but not upon copper.

When calx of iron is mixed with that of cobalt in a flux, the former is diſſolved.

Mineralized Cobalt.

Cobalt, in fuſion, takes up about one third of its own weight of ſulphur, but then aſſumes ſo refractory a nature, that it can ſcarcely be fuſed. Iron, copper, and ſeveral other metals, precipitate cobalt.

The common ore, by roaſting and fuſion, yields a regulus, though an impure one.

The green cobalt, which I have hitherto examined, tinges the microcoſmic ſalt indeed of a blue, but at the ſame time ſhews red ſpots indicating copper.

§ XXXIII. *Zinc, reguline and calcined.*

Fuſed zinc takes fire, ſending forth a lanuginous white calx, which ſoon extinguiſhes the beautiful bluiſh green flame; but if the reguline nucleus, included in this lanuginous matter, be urged by the fire, it is inflamed now and then, but flies about, and as it were explodes.

When added to borax, it excites a ſpumeſcence, and at firſt tinges the flame; it continually diminiſhes, and the flux ſpreads upon the charcoal: but in fuſed microcoſmic ſalt it not only occaſions ſpumeſcence, but ſends forth ſeveral flaſhes, with a crackling noiſe. By too great heat it explodes, ſending forth ignited particles.

The white calx, expoſed to the flame on the charcoal, puts on a yellowiſh ſplendor, which, when the flame ceaſes, vaniſhes—it remains fixed and refractory. The fluxes are ſcarely tinged, but when ſaturated by fuſion, on cooling grow opake and white. Around the globules clouds appear, which are of a nature ſimilar to that of the metallic calx.

Diſſolved zinc is not precipitated by any other metal.

That zinc which contains aerial acid has the ſame properties as calcined zinc.

In the pſeudo galenæ ſulphur is preſent by means of iron. Theſe in general (upon the charcoal) ſmell of ſulphur, fuſe, and tinge the flame more or leſs, depoſiting a cloud all around. The fluxes diſſolve; thoſe which have no matrix are tinged by thoſe which contain iron, and by ſaturation acquire a white opacity, which verges to brown or black, according to the variety of compoſition.

§ XXXIV. *Antimony, reguline and calcined.*

Regulus of antimony, fuſed, and ignited upon the charcoal, affords a beautiful object; for if the blaſt of air be ſuddenly ſtopped, a white ſmoke riſes copiouſly and perpendicularly, while in the mean time the inferior part round the globule is condenſed into cryſtalline ſpiculæ, analogous to thoſe which are commonly called argentine flowers.

The calx tinges fluxes of an hyacinthine colour, but on fuſion ſmokes, and is eaſily diſſipated, eſpecially on the charcoal; yet it alſo there depoſits a cloud.

The diſſolved metal may be precipitated by iron and copper, but not by gold.

Mineralized Antimony.

Crude antimony liquefies upon the charcoal, ſpreads, ſmokes, penetrates it, and in concluſion diſappears totally, except a ring which it leaves behind.

§ XXXV. *Manganeſe, reguline and calcined.*

The regulus of manganeſe ſcarcely yields to the flame; for a ſmall particle is eaſily calcined, and a large one cannot be made ſufficiently hot.

The black calx imparts a bluiſh red colour to the fluxes; the tinge of borax, unleſs well ſaturated, is more yellow. The colour may be gradually altogether deſtroyed by the interior flame, and again re-produced by a ſmall particle of nitre, or the exterior flame alone; theſe changes may be alternated *ad libitum*.—The cauſe of this is elſewhere explained.

When loaded with aerial acid it is of a white colour, which by ignition is ſoon changed to a black.—In other reſpects this ſhews the ſame phænomena as the black calx.

§ XXXVI. *Concluſion.*

From what has been ſaid I think it apparent, that the blow-pipe is an inſtrument extremely uſeful, nay neceſſary, to chemiſts; for many experiments are daily neglected, 1ſt, Becauſe they require furnaces, and a large apparatus of veſſels;—yet many of theſe may eaſily be performed by means of the apparatus above deſcribed: 2d, From the want of time neceſſary for examining in the ordinary

ordinary way ;—whereas the experiments above mentioned may be finiſhed in a few minutes : 3d, The uſual method of examination requires a certain quantity of the matter to be examined, which prevents the examination of ſuch as are ſcarce or dear; —but in our way the ſmalleſt particle is ſufficient.

However, the conveniencies now deſcribed, though of great weight, are attended with this defect, that they do not determine the proportions, or at leaſt point them out but very inaccurately, and therefore are not to be preferred to the larger trials, unleſs when time or other circumſtances prevent them. But the firſt enquiry to be made is, what a ſubſtance contains, not how much: and I have learned, by the experience of many years, that theſe trials in ſmall ſuggeſt the proper method of inſtituting experiments at large. Theſe experiments have beſides ſome advantages over thoſe conducted in crucibles, *viz.* we can ſee all the phænomena from beginning to end, which wonderfully illuſtrates the ſeries of operations, and their cauſes (§ XXI. XXX.—XXXV.), Experiments made in crucibles are often fallacious, as the ſubſtance of the veſſel itſelf is corroded. —We ſuppoſe that lime or magneſia, melted with fixed alkali, are united with it in the way of ſolution; but the globule, when well fuſed in the ſpoon, by its tranſparency permits us plainly to ſee that, except the

ſiliceous

ſiliceous part, it is only mechanically mixed (§ XVI.). The moſt intenſe degree of heat may in this way be obtained in a few minutes, which is ſcarcely obtained in many hours in a crucible (§ XIII. XXIII.).

This may be ſufficient for the commendation of the blow-pipe;—thoſe who uſe it will gradually diſcover more of its valuable properties.

END OF THE SECOND VOLUME.